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CH2MHILL

31 March 2005

Mr. Jonathan S. Davis
Remediation Program Manager
HQ AFCEE/MMR
322 East Inner Road
Otis ANG Base, MA 02542-5028

SUBJECT: AFCEE ENRAC F41624-01-D-8545; Task Order 0071
MMR SPEIM/LTM/O&M Program
CDRL #A012
Ashumet Pond Geochemical Barrier for Phosphorus Removal Installation Summary Report

Dear Mr. Davis:

As directed by the Air Force Center for Environmental Excellence, CH2M HILL is hereby providing for your review one copy of the document entitled *Ashumet Pond Geochemical Barrier for Phosphorus Removal Installation Summary Report* dated March 2005.

If you have any questions or comments, please contact me at (508) 968-4670, extension 5988.

Sincerely,

CH2M HILL

N. Tindall for

Marc W. Slechta, P.G., L.S.P.
Program Manager

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Massachusetts Military Reservation

AF CENTER FOR ENVIRONMENTAL EXCELLENCE

Ashumet Pond Geochemical Barrier for Phosphorus Removal Installation Summary Report

March 2005

Prepared for:
AFCEE/MMR
Installation Restoration Program
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ACRONYMS AND ABBREVIATIONS

AFCEE	Air Force Center for Environmental Excellence
ANOVA	analysis of variance (test)
APTHM	Ashumet Pond Trophic Health Technical Memo
cm	centimeter
CMR	Code of Massachusetts Regulations
cy	cubic yard
DEP	Massachusetts Department of Environmental Protection
DO	dissolved oxygen
ECC	Environmental Chemical Corporation
EPA	U.S. Environmental Protection Agency
FCC	Falmouth Conservation Commission
$Fe(OH)_3$	oxidized iron (amorphous ferric hydroxide)
$FePO_4$	ferric phosphate
ft	feet
gms	grams
gpm	gallons per minute
HDPE	high-density polyethylene plastic
IRP	Installation Restoration Program
kg	kilogram
L	liter
lb	pound
L/day	liter per day
lf	linear foot
m^2	square meter
mg	milligram
MGL	Massachusetts General Laws
MHC	Massachusetts Historic Commission
MMR	Massachusetts Military Reservation

ACRONYMS AND ABBREVIATIONS

msl	mean sea level
NHESP	Natural Heritage and Endangered Species Program
NOI	Notice of Intent
NWQL	National Water Quality Laboratory
OOC	Order of Conditions
P	phosphorus
PAL	Public Archaeology Lab
PMP	Phosphorus Management Plan
PO_4^{-3}	phosphate ion
PVC	polyvinyl chloride
SMAST	University of Massachusetts, Dartmouth, School of Marine Science and Technology
SPEIM	System Performance and Ecological Impact Monitoring
STP	sewage treatment plant
UMASS	University of Massachusetts
USACE	U.S. Army Corps of Engineers
USC	U.S. Code
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
yr	year
ZVI	zero valent iron

EXECUTIVE SUMMARY

Ashumet Pond is a roughly 215-acre kettle hole pond located near the Massachusetts Military Reservation (MMR) on Cape Cod. A phosphorus-rich groundwater plume originating from the former sewage treatment plant (STP) at the Massachusetts Military Reservation (MMR) has been discharging to Ashumet Pond for at least 20 years. Due to the strong upward hydraulic gradients along the shore of Ashumet Pond, the bulk of this phosphorus plume is discharging within about 50 feet of the shoreline. The section of the pond bottom where most of the phosphorus plume is upwelling is referred to as the "plume footprint." It has been a concern that the continued loading of excess phosphorus to Ashumet Pond represents a potential threat to its trophic health.

Following extensive evaluation of the phosphorus plume and the trophic health of Ashumet Pond, AFCEE recommended a two-part strategy for addressing phosphorus loading to the pond. The first part of the strategy was to address phosphorus loading through targeted inactivation of phosphorus in the hypolimnion of the pond. This element was implemented in Fall 2001 (AFCEE 2002). The second part of the strategy, and the focus of this report, involved the design and installation of a geochemical barrier to reduce the flow of phosphorus to the pond. The *Final Ashumet Pond Geochemical Barrier for Phosphorus Removal Design Testing & Installation Workplan* (AFCEE 2004) (i.e., *Workplan*) for the installation of the barrier was developed during Spring/early Summer 2004 after the final barrier design testing was completed. The *Workplan* includes, but is not limited to, preliminary barrier evaluation, field and laboratory proof-of-concept tests, design details, and permits.

The geochemical barrier installation was completed between 11 August 2004 and 16 September 2004. Installation was consistent with the *Workplan*, associated permits and related correspondence. Quality assurance sampling and analysis was conducted and verified that the barrier was consistent with design. Pre-installation monitoring was conducted to document pre-barrier conditions and to provide a baseline for comparison to post-installation monitoring results. Samples were collected via temporary drive points,

piezometers, small interval multi-level profilers, interface diffusion samplers, horizontal multi-level samplers, and seepage meters.

Initial performance data indicate that a reduction in phosphorus concentrations of up to two orders of magnitude is occurring as water moves vertically through the barrier. The data suggests that most of the phosphorus reduction is occurring within the first foot of barrier thickness. It is expected that the effectiveness of the barrier will increase with time. Given the conservatism of the barrier design assumptions, it is believed that the barrier will effectively sequester phosphorus in groundwater moving through the sediments for up to twenty-five years.

Post-installation monitoring data of seepage meters and interface diffusion chambers will be further evaluated. In addition, a long-term performance monitoring plan will be developed and implemented for the Ashumet Pond geochemical barrier. The results of data evaluation and monitoring events will be summarized in future reports.

1.0 INTRODUCTION

1.1 SITE DESCRIPTION AND HISTORY

Ashumet Pond is a roughly 215-acre kettle hole pond located near the Massachusetts Military Reservation (MMR) on Cape Cod (Figure 1). This pond is fed primarily by groundwater seepage and it has no surface water outlet. A phosphorus-rich groundwater plume originating from the former sewage treatment plant (STP) at the Massachusetts Military Reservation (MMR) has been discharging to Ashumet Pond for at least 20 years (Figure 2). Due to the strong upward hydraulic gradients along the shore of Ashumet Pond (AFCEE 2002a) the bulk of this phosphorus plume is discharging within about 50 feet (ft) of the shoreline (Figure 3). The section of the pond bottom where most of the phosphorus plume is upwelling is hereafter referred to as the "plume footprint" (Figure 2).

Early source control measures for the STP plume, instituted in the mid 1980s, involved management of sand filter bed loading to minimize flow toward Ashumet Pond. The discharge of treated wastewater from the STP to the sand filter beds was eliminated in December 1995. Despite these early efforts, a large mass of easily mobilized phosphorus remains adsorbed to the aquifer matrix between the former STP and Ashumet Pond. This large reservoir of mobile phosphorus remaining in the aquifer is expected to continue contributing elevated levels of phosphorus to groundwater, and ultimately to the pond, for decades (McCobb et al. 2003). Based on a recent U.S. Geological Survey (USGS) groundwater model, phosphorus (P) loading to the pond from the STP plume is in the range of 69-101 kg/yr (LeBlanc, USGS, personal communication). These recent USGS phosphorus loading estimates are consistent with the phosphorus loading estimates reported in the *Final Ashumet Pond Trophic Health Technical Memorandum* (AFCEE 2002a) and several other earlier Ashumet Pond investigations (e.g., K-V Associates 1991; Walter et al. 1995).

It has been a concern that the continued loading of excess phopshorus to Ashumet Pond could represent a potential threat to the future trophic health of the Pond (e.g., K-V Associates 1991; Walter et al. 1995). In response to this concern, AFCEE initiated an intensive investigation to evaluate the trophic health of the pond during the 1999 Spring/Summer season. This investigation, in combination with a detailed evaluation of earlier investigations and historical data, were presented in the *Final Ashumet Pond Trophic Health Technical Memorandum* (APTHM) (AFCEE 2002). Periodic pond surface water quality monitoring has been conducted since 1999.

1.2 PHOSPHORUS REMEDIATION EFFORTS

Following extensive evaluation of the phosphorus plume and the trophic health of Ashumet Pond, AFCEE recommended a two-part strategy for addressing phosphorus loading to the pond. The first part of the strategy was to address phosphorus loading through targeted inactivation of phosphorus in the hypolimnion of the pond. This element was implemented in Fall 2001 (AFCEE 2002). Subsequent monitoring has demonstrated that this effort successfully reduced the phosphorus loading from sediments within the hypolimnion. The second part of the strategy involved the design and installation of a geochemical barrier to reduce the flow of phosphorus to the pond via groundwater discharge. The geochemical barrier contains zero-valent iron (ZVI) filings mixed with pond bottom sediments and is situated along the shoreline of the pond in the area of phosphorus discharge (Figure 2, Figure 3, and Figure 4).

The strategy was presented in a document entitled the *Draft Phosphorus Action Recommendation/Schedule* (AFCEE 2000). The evaluation of specific remedial approaches and specific recommendations was presented in the *Final Ashumet Pond Phosphorus Management Plan* (AFCEE 2001). The *Final Ashumet Pond Geochemical Barrier for Phosphorus Removal Design Testing & Installation Workplan* (AFCEE 2004), hereafter referred to as the *Workplan*, presents the design basis for the geochemical barrier, the implementation strategy, and related permitting and other work supporting the project. The geochemical barrier installation was completed between 11 August 2004 and 16 September 2004, as discussed in Section 4.0.

The initial performance data, which is further discussed in Section 7.1, indicates that the barrier is effectively reducing loading of phosphorus to the pond. Additional monitoring work will be conducted as part of the AFCEE Installation Restoration Program (IRP) Ashumet Valley groundwater plume long-term monitoring program (i.e., System Performance and Ecological Impact Monitoring [SPEIM] program). This information will be presented in future reports.

1.3 REPORT OBJECTIVES

The primary objectives of this report are to: (1) summarize the pre-installation planning activities; (2) summarize the pre-installation baseline monitoring results; (3) describe the barrier design and installation process; (4) present the methods and results of the initial post-installation performance monitoring; (5) evaluate phosphorus removal performance of the barrier; (6) discuss barrier post-installation activities; and (7) identify recommendations for future pond barrier monitoring approaches.

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2.0 PRE-INSTALLATION PLANNING SUMMARY

To support the geochemical barrier project, laboratory and field studies were completed by AFCEE, AFCEE's contractors, the USGS, and the University of Massachusetts, Dartmouth, School of Marine Science and Technology (SMAST). This work, as summarized in the *Workplan*, included groundwater modeling and field activities to assess groundwater seepage (i.e., flux) to the pond; mapping of the "discharge footprint" for groundwater containing elevated phosphorus; literature searches related to geochemical barriers and use of ZVI; laboratory and field studies evaluating ZVI in surface and mixed-sediment applications; laboratory studies to support final design characteristics of the barrier (e.g., ZVI content and barrier dimensions); evaluation of approaches for barrier construction; assessment of permitting requirements; and associated design/implementation adjustments to ensure compliance with permitting requirements.

2.1 WORKPLAN DEVELOPMENT

The *Workplan* was developed during Spring/early Summer 2004 after final laboratory studies were completed. Preliminary barrier evaluations involving proof-of-concept field test plots and proof-of-concept laboratory column tests had been initiated in June 2001. Field test plots were installed in June 2001 and were subsequently monitored to evaluate performance. Laboratory column tests were conducted from July 2001 through May 2003. Final barrier design testing followed these efforts and was conducted during the Fall/Winter 2003/2004. The primary objectives of the testing were: 1) to confirm that a ZVI barrier was an appropriate remedial action for Ashumet Pond; and 2) to obtain additional performance data necessary to develop a barrier design appropriate for a targeted area within the phosphorus plume discharge footprint. During the design process it was concluded that a barrier utilizing ZVI as a source of oxidized iron would be effective in removing substantial amounts of dissolved phosphorus from groundwater discharging to the pond.

As part of workplan development for construction of the geochemical barrier, cultural and natural resource agencies were consulted to ensure that the project would be implemented in a manner protective of these resources. The overall objective of the geochemical barrier project was to enhance the trophic health and ecological conditions of Ashumet Pond. However, it was understood that some short-term impacts to benthic habitat within the barrier area may result from the barrier construction effort. To better characterize the area, a biological resource survey was completed during the development of the barrier design/workplan (AFCEE 2004). Interaction with permitting agencies and other reviewers, including the Massachusetts Historic Commission, the Board of Underwater Archaeology, and the Natural Heritage and Endangered Species Program, enabled AFCEE to refine the approach to the project to be further protective of both natural and cultural resources.

The phosphorus removal processes that were expected to dominate within and adjacent to the barrier are: 1) sorption onto amorphous ferric hydroxide (hereafter $Fe(OH)_3$); 2) direct precipitation of ferric phosphate from solution; and 3) the co-precipitation of phosphorus with $Fe(OH)_3$. The *Workplan* describes these processes in detail.

Table 1 summarizes key barrier design parameters and characteristics.

2.2 PROPERTY EASEMENT AND ACCESS APPROVALS

This section describes the private and public property access work that was necessary prior to the commencement of barrier construction activities.

Private Property Access

The McMahon family owns the property along the Ashumet Pond shoreline adjacent to the geochemical barrier footprint within the town of Falmouth. The property is identified as Lot 0901005000 on the corresponding Falmouth Assessor's Map. Throughout the years, AFCEE and the USGS have worked closely with the McMahon family regarding plume monitoring and studies leading to the design of the geochemical barrier. In

September 2004, a formal 20-year easement agreement was executed between the federal government and the McMahon family. This easement agreement provides access for AFCEE IRP activities including soil/sediment and groundwater monitoring, barrier maintenance, and barrier removal activities, if necessary. This easement assumes that the government will be responsible for obtaining/maintaining any necessary federal, state, and local permits.

Public Property Access

Access and permission to use the Ashumet Pond State Boat Ramp during the construction phase of the project was obtained through coordination with the Southeast Regional Office of the Commonwealth of Massachusetts, Department of Fish and Game, Division of Fisheries and Wildlife and the Public Access Board.

Other reviews by the Commonwealth to protect public interests relating to inland waterways were conducted through the state Chapter 91 review/permitting process. The following section provides a summary of the permitting process.

2.3 PERMITTING SUMMARY

Permitting work for the project was conducted in parallel with development of the *Workplan*. A draft *Workplan* was attached to permit applications forwarded to permitting authorities including the Town of Falmouth Conservation Commission (FCC), the Massachusetts Department of Environmental Protection (DEP) Wetlands and Waterways staff, the U.S. Army Corps of Engineers (USACE), and other parties involved in the review of permit applications (e.g., Coastal Zone Management and the U.S. Environmental Protection Agency, Region 1). Public comment periods were held for each of the permit applications and a Falmouth Conservation Commission public hearing was conducted. No formal public comments were received. The draft *Workplan* was revised and finalized to incorporate recommendations and requirements from the permitting agencies and other environmental review authorities. The *Workplan* includes copies of final permits.

The following is a brief summary of key permits, correspondence, and requirements associated with the project:

Town of Falmouth Order of Conditions – DEP Wetland File # SE 25-3004 (Wetlands Protection Act, MGL c. 131, Sect. 40 and associated regulations (310 CMR 10.000 and Town of Falmouth Wetlands Bylaw and Regulations), dated 02 July 2004 (Appendix A).

- DEP Letter, Notification of Wetlands Protection Act File Number – Assigns File # SE 25-3004 and Notice of Intent (NOI) review indicated need for dredging permits (per Clean Water Act Sect. 404, MGL c. 91, Clean Water Act Section 401 Water Quality Certification), dated 15 June 2004.
- The Falmouth Conservation Commission Order of Conditions (FCC OOC), dated 02 July 2004, required that the boundary of Bordering Vegetated Wetlands adjacent to the work area be flagged prior to the initiation of field activities, that conditions in the area before and after construction be photo-documented, and that wetland and upland vegetation disturbed during construction be restored. In addition, the FCC OOC required that a Certificate of Compliance be obtained and registered with Barnstable County Registry of Deeds. Specifically, FCC OOC Special Condition #5, states that "no Certificate of Compliance will be issued until the entire project, including landscaping is completed and the site is permanently stabilized with vegetation." Due to the performance of field construction work late in 2004, AFCEE plans to develop final documentation of post-construction site conditions to support the application for a Certificate of Compliance in the Spring 2005.

DEP Chapter 91 Permit – Permit No. 10084 (Public Waterfront Act, MGL c. 91 and Regulations 310 CMR 9.00), dated 03 August 2004.

- The Chapter 91 permit required that before (pre-construction) and after (post-construction) bottom surveys of the pond bottom/shoreline area be conducted to ensure that, "dredging under this Permit … be conducted so as to cause no unnecessary obstruction of the free passage of vessels, and care shall be taken to cause no shoaling."

DEP 401 Water Quality Certification - DEP Wetland File # SE 25-3004 (MGL c. 21, Sect. 26-53 and 314 CMR 9.00) and Federal Clean Water Act as amended, 33 USC Sect. 1251 et seq.), dated 21 July 2004.

- AFCEE letter to DEP Wetlands and Waterways, dated 30 July 2004 – final permit clarifications and minor project adjustments.

- The 401 Water Quality Certification stated that "any necessary dewatering shall be conducted in such a manner and strictly monitored to prevent sediment from impacting wetland areas and waterways."

U.S. Army Corps of Engineers 404/Category II Activity under Federal permit, Massachusetts Programmatic Permit and inclusive of Federal Consistency Review by Massachusetts Coastal Zone Management [Permit No. 2004-1645 (Clean Water Act 33 USC 1344), dated 16 July 2004, Department of Army, Programmatic General Permit, Commonwealth of Massachusetts, dated 30 June 2003].

- In accordance with the USACE, Clean Water Act, Section 404 Category II Programmatic General Permit, "upon completion of construction, all disturbed wetland area (the disturbance of these areas must be authorized) shall be stabilized with a wetland seed mix containing only plant species native to New England."

Massachusetts Department of Fish and Game Public Access Board – 2004 Special Use Permit No. 736, dated 25 May 2004

- To satisfy concerns identified by Massachusetts Department of Fish and Game, a plan for temporary use of a portion of the boat ramp parking lot for staging of equipment and supplies was developed to ensure that the access to the State boat ramp would not be impeded during the construction project.

Associated Correspondence and Related Requirements

- Natural Heritage and Endangered Species Program (NHESP) review: Letter of 23 June 2004 - NHESP File No. 00-7695
- AFCEE response to NHESP and permitting agencies: Letter of 14 July 2004
- Massachusetts Historic Commission Reviews (MGL c. 9, Sect. 26-27C) and regulations: Letters of 11 June 2004 and 13 July 2004 – MHC #RC.35161
- Board of Underwater Archaeology: Letter of 03 June 2004
- In response to comments of the MHC, Bureau of Underwater Archaeology, and the NHESP, a high density polyethylene (HDPE) grid mat system was incorporated into the project to protect the shoreline between Fisherman's Cove and the excavation area from both a rare species habitat and potential cultural resource perspective. In addition, the floating boom/silt curtain alignment was modified to ensure protection of the potential sandy bottom habitat for a state-listed species of special concern [Tidewater Mucket *(Leptodea Ochracea)*].

A letter to the DEP Wetland and Waterways Program and other permitting authorities, dated 30 July 2004 (provided in Appendix A) documents final project refinements. These refinements related to clarification of material dredge volumes represented in the 401 Water Quality Certification, *Workplan* adjustments associated with response to NHESP concerns; Environmental Chemical Corporation's (ECC) desire to make a field determination relative to the optimal size of the area to be contained within the Aquabarrier® cofferdams; and notification relating to the USGS installation of barrier performance monitoring devices prior to, and concurrent with, barrier installation.

Once permit reviews were completed, revisions were made to the *Workplan* and the document was finalized prior to the initiation of field activities. Section 6.0 provides a discussion of post-barrier installation permit compliance activities.

3.0 PRE-INSTALLATION BASELINE MONITORING

AFCEE, in association with its contractors and the USGS, has conducted a number of groundwater monitoring events in the vicinity of, and within, Ashumet Pond. Results of these monitoring events have defined the phosphorus plume groundwater discharge footprint. The plume discharge footprint has been fairly consistent over several years. The footprint extends from Fisherman's Cove around the point to the northeast. It should be noted that the area of shoreline to the east (Figure 2) has typically been where the highest concentrations of phosphorus have been detected. This is also where the groundwater flux rate is expected to be the greatest due to a generally more sandy/gravelly substrate relative to that within the Cove. The barrier design was selected to enclose the majority of this footprint area. Prior to the installation of the barrier, the USGS conducted several activities to test barrier performance monitoring methods in order to design an effective barrier performance monitoring network.

The pre-installation monitoring activities are summarized below. The data obtained during these pre-installation monitoring activities are presented as tables and figures in Appendix B.

Temporary Drive Point Sampling. The objective of the temporary drive point sampling was to capture the spatial distribution of phosphorus in pore water at three ft below the pond bottom (the depth corresponding to the bottom of the barrier) immediately prior to barrier installation. One hundred and four temporary drive points were installed and sampled by the USGS in late June/early July 2004. Samples were analyzed for dissolved phosphorus and specific conductance. The drive points were located in the general vicinity of the planned barrier area (Figure 5 and Appendix B). Each drive point was pushed to a depth of three ft below the pond bottom. A sample was collected at that depth. Figure 6 is a photograph of the field crew collecting drive point samples from a small aluminum boat positioned with stabilizers.

Figure 7 depicts the contoured phosphorus results of this "pre-barrier" monitoring and indicates that the dissolved phosphorus discharge footprint had characteristics similar to

that encountered in past sampling events. The data confirmed that the 40-ft by 300-ft area planned for barrier construction was appropriate. The higher concentrations of phosphorus (greater than 1 milligram per liter [mg/L]) were located in the center of the barrier area.

Seepage Meter Grid. In August 2004, groundwater flux rates were monitored and dissolved phosphorus was sampled at 88 temporary seepage meter locations by the USGS. These data are currently being evaluated and results will be presented in future reports. Groundwater seepage data collected prior to August 2004 indicate that the highest seepage rates are expected near the pond shoreline within the discharge footprint. This suggests that the greatest flux of phosphorus associated with the phosphorus plume occurs in this area.

Piezometer Clusters. In June 2004, two clusters of piezometers (FG35P01 and FG36P01) were installed 55 ft and 110 ft, respectively, from the shoreline. The purpose of sampling these piezometers was to better define the vertical distribution of the phosphorus plume and vertical piezometric heads at locations near the area of plume discharge. Figure 5 and Figure 7 show the location of these piezometers. These data are currently being evaluated and results will be reported in future reports.

Temporary Small-Interval Multi-Level Profiling. In July 2004, small-scale vertical multi-level concentration profile samples were collected at ten locations (nine within and one outside the planned barrier area) using a portable multi-level drive point device. Figure 8 shows the ten drive point locations. Samples were collected at 0.8, 1.6, 2.2 and 3.4 ft below the pond bottom. Data showed that phosphorus concentrations in pore water within the planned barrier area were fairly consistent in the vertical profile, showing an increase in phosphorus concentration with depth.

Following construction of the barrier, permanent small-interval multi-level samplers were installed at the same ten locations to provide vertical profile data. The vertical data collected during the pre-construction sampling (i.e., baseline) is discussed with the post-barrier installation data in subsequent sections of the report.

4.0 BARRIER INSTALLATION

4.1 PRE-CONSTRUCTION PLANNING

AFCEE and its construction contractor and its design/oversight contractor conducted periodic construction coordination meetings during the final stages of permitting and *Workplan* completion. These meetings were held to identify potential scheduling issues, assess field conditions, and identify other circumstances that may impact the project schedule or construction methodologies. Routine coordination meetings continued through the pre-construction period and during construction.

Implementation challenges were minimized due to extensive field and bench pilot testing of ZVI, planning and permitting work conducted with various federal, state, and local agencies, and field testing of barrier monitoring technologies prior to installation. The project team made adjustments to the field approach throughout the development of the *Workplan* and completion of final permitting documents.

With all permits in place, AFCEE issued a Notice to Proceed with field construction work on 30 July 2004 in accordance with the Falmouth Conservation Commission (FCC) 06 July 2004 Order of Conditions, Standard Condition #13. This notice was forwarded to the FCC and other permitting authorities.

On 19 August 2004, a pre-excavation elevation survey of the pond bottom within the barrier installation area was performed. The survey was conducted to evaluate pond bathymetry prior to barrier construction and to allow for a comparison to post-construction pond bathymetry. This pre-construction bathymetric survey mapping work was conducted in accordance with the Chapter 91 permit (Permit No. 10084, 03 August 2004). The post-construction bathymetric survey is discussed in a later section of this report.

Prior to the commencement of construction activities, photographs were taken of the barrier construction area and the shoreline utilized to access the area to document field conditions.

Schedules for construction implementation were coordinated with the Department of Fish and Game, Division of Fisheries and Wildlife, Southeast Regional Office and the Public Access Board. This activity was important since the boat ramp parking lot at Fisherman's Cove was needed for staging of equipment and access to the construction site. Plans were made to conduct the work during times that did not conflict with fishing tournaments or high recreational use periods. The work was scheduled to occur during the normal five-day work week during August and early September 2004.

Materials and equipment was received and staged at MMR during *Workplan* finalization in order to commence work as soon as possible after AFCEE issued the Notice to Proceed. Final preparations were made prior to the planned in-field start date of 09 August 2004. A Bordering Vegetated Wetlands survey was completed along the shoreline of the work area to ensure that wetlands species in adjacent areas would be protected (as required by the FCC OOC). Permit postings were established at the worksite as required. Field construction activities were underway on 11 August 2004, with initiation of construction of the HDPE grid mat system at Fisherman's Cove.

The following sections provide details related to the installation activities.

4.2 MOBILIZATION AND CONSTRUCTION EQUIPMENT

To complete the primary construction aspects of the project, the following equipment was mobilized to the project site:

- One PC 200 excavator equipped with an Allu screening/mixing bucket
- One Caterpillar 312 excavator
- One Lull 844 extendable fork lift
- One 12-inch Dri Prime ™ pump, suction and discharge hose

- Two 6-inch Dri Prime ™ pumps, suction and discharge hose
- Two 4-inch Dri Prime ™ pumps, suction and discharge hose
- One hundred 14 ft x 8 ft High density polyethylene plastic (HDPE) grid/mat system
- Six Water-bladder cofferdams (Aquabarriers®)
- Twenty-nine 3,000 lb super sacks of zero valent iron (Peerless 8/50 Cast Iron Aggregate)

4.3 ACCESS TO THE BARRIER CONSTRUCTION AREA

Access to and from the barrier installation area was identified as a key challenge during the development/planning stages of the project. This issue involved consideration of whether equipment and supplies would be transported from the boat ramp staging area along the narrow shoreline, over water, or both. As previously discussed, MHC and the NHESP identified that the shoreline surface should be physically protected to minimize potential impact to benthic habitat and any cultural resources that might be present. To address this challenge, an HDPE grid mat system was incorporated into the project plans. Each HDPE grid mat was 14 ft wide and 8 ft long. Mats were connected with locking pins. This produced a stable and protective access surface leading from the boat ramp around the shoreline to the barrier construction area. This "access road" was the main route for all equipment including pumps, excavators, and fork lifts.

In addition, plans were made to store the major equipment (excavators) in the shoreline work area throughout the project. This plan allowed for shoreline protection from damage/erosion caused by daily construction equipment moves.

4.4 DEWATERING OF THE BARRIER EXCAVATION AREA AND SILTATION CONTROL

During field preparations, the decision was made to combine the three originally planned cofferdam/excavation sub-areas into one large area contained within a single Aquabarrier® cofferdam set-up. This approach, rather than three cofferdam subareas originally considered, eliminated the need for ongoing pumping, equipment moves, and

refilling of Aquabarriers® throughout the project. Two different views of the site during installation of the HDPE grid mat system installation along the shore of Fisherman's Cove are presented in Figure 9.

A floating boom with silt curtain was installed around the excavation area, including the pump discharge locations. In addition, a floating boom without a silt curtain was extended along the shoreline to provide spill containment protection immediately offshore from the HDPE grid/mat system. The floating boom was intended to provide containment should any release of fuels, oil, or hydraulic fluid from excavation or other construction equipment occur as they operated along the HDPE grid mat accessway. No releases occurred during the construction period.

Each morning dewatering pumps were turned on and operated throughout the workday to dewater the excavation area. Figure 10 shows one of the three pumps used for dewatering. During construction activities, control of pond water leakage beneath and between the Aquabarrier® water-bladder cofferdams was a challenge. It was initially estimated that two 6-inch pumps and one 4-inch pump would be sufficient to dewater the cofferdam area. This proved to be insufficient. As a result, an additional 12-inch pump was mobilized to the work area to replace the 4-inch pump. The amount of water pumped was estimated to be roughly 4,000 to 5,000 gallons per minute (gpm). This pumping lowered the water level in the work area by approximately 24 to 30 inches in order to perform excavation, ZVI/sediment mixing, and backfilling in a controlled, though wet, environment. It was originally envisioned that the area would be more completely dewatered prior to excavation; however, the significantly lowered water level provided sufficient control to enable excavation work to proceed.

Filtration of pumped water prior to discharge was also a challenge since the quantity of water to be managed was greater than originally expected. The plan was to use a bag filter train capable of filtering 400 gpm; however, since the actual estimated flow was over ten times that amount, the filtering process had to be modified. The first modification was the use of 50-micron filter bags which were secured to the ends of the 6-inch discharge lines to filter the discharge water associated with the 6-inch pumps.

Secondly, the high discharge water flow from the 12-inch pump was passed through a non-woven geotechnical fabric in order to sufficiently filter the water. Both applications were effective at reducing the turbidity of the discharge water. However, as the excavation grids approached the end near the 12-inch pump, the turbidity did increase. Refer to Section 4.5 (below) for a discussion of turbidity measurements.

4.5 EXCAVATION, ZVI MIXING, AND REPLACEMENT

Excavation grids were laid out, starting with "Grid 1" (30 ft by 40 ft) at the northern end of the barrier and continued from the northeast to the southwest. Bottom materials were excavated to a depth of approximately three ft below the pond bottom and were screened to remove coarse gravel and cobbles.

Throughout the excavation/mixing portion of the project, one excavator was used to excavate sediments and place sediments mixed with ZVI back in the excavation. The other excavator with the Allu® screening bucket was used for mixing of ZVI with excavated sediments in staged piles. Figure 11 shows the excavation and mixing process. Appendix C provides other key photos documenting the construction project.

Slumping along the edges of each grid excavation meant that clean excavated cuts along the margins of each grid cell could not be maintained. This was overcome by slightly overlapping excavation boundaries when the excavators completed one grid cell and moved to adjoining cells.

On the first day of excavation, Grid 1 was completed and set-up for the additional grids was accomplished. After completion of the first grid, it was determined that the screening process produced a fairly small volume of gravel/cobbles. This indicated that the screening process would not yield a significant armoring layer for placement back over the excavation area following emplacement of sediment mixed with ZVI. Consequently, AFCEE made the determination that screening would not continue during the remainder of the excavation/mixing/emplacement process.

On the second day of barrier installation activities, Grids 2, 3, and 4 were completed. On the third day, Grids 5, 6, and 7 were completed and on the fourth day, Grids 8, 9, and 10 were completed.

Turbidity measurements were collected throughout the excavation activities near the discharge outlet for the 12-inch pump, which was on the south side of the excavation area. This was to keep the release of turbid water to a minimum and within the silt curtain. Background turbidity measurements were collected near the boat ramp. The background measurements and discharge location measurements are summarized in Table 2.

These data indicate that average turbidity at the discharge location (within the silt curtain) increased as the excavation work progressed to the southeast (e.g., toward the large pump intake). Due to this increase, additional turbidity measurements were collected in Ashumet Pond immediately beyond the silt curtain on 26 August and 30 August. These data indicate that the containment approach (e.g., Aquabarriers®, filters on the discharge line, silt-curtain) effectively entrained silt within the secondary containment (silt curtain) area. Turbidity measurements outside the silt curtain were consistent with background turbidity measurements.

Once sediments in all the grid areas were excavated, mixed, and replaced, post-installation sediment samples were collected and construction demobilization began. The quality assurance analyses conducted during and immediately after construction are discussed in Section 4.7.

4.6 CONSTRUCTION DEMOBILIZATION

Demobilization commenced on 31 August 2005 with the initiation of the removal of the Aquabarriers®. Final demobilization was completed on 13 September 2004 with completion of the post-barrier bathymetric survey.

4.7 BARRIER FIELD CONSTRUCTION QUALITY ASSURANCE ANALYSIS

In accordance with the *Workplan,* the construction contractor collected pre-installation, post-mixing/pre-backfill, and post-installation sediment samples for construction quality assurance purposes.

Ten samples were collected across the footprint of the planned excavation area from the surface to one foot below grade prior to excavation activities. These pre-installation samples were collected on 28 June 2004, and were analyzed for iron, manganese and total phosphorus (Table 3). Figure 12 shows the location of these ten pre-installation samples. The average iron concentration was 2,126 mg/kg (excluding the duplicate 03FD08 sample).

Post-mixing, pre-backfill samples were collected on 24, 26, and 30 August. On the first day of excavation/mixing, one grab sample (AP-S000101) was collected from the sediment stockpile prior to adding ZVI. Seven grab samples (AP-S000102 through AP-S000108) were collected from the stockpile after mixing with ZVI for approximately one hour. The baseline sample had an iron concentration of 1,990 mg/kg and the average for the other samples collected after mixing was approximately 71,500 mg/kg. Due to the variability of iron in samples collected on the first day of excavation/mixing (33,000 mg/kg to 135,000 mg/kg), adjustments were made to the mixing process to improve the uniformity of the ZVI sediment mixture.

Two additional sampling events were conducted on 26 August and 30 August to evaluate the mixing process. The stockpiles were divided into three sections (top, middle, and bottom) for sampling purposes. Data from Grids 6, 7, 8, and 9 indicate marginal improvements to the variability of iron concentrations in mixed sediment.

Grain-size analyses conducted on samples collected on 26 and 30 August indicate that the sediments are fairly uniform with sand and gravel generally over 98 percent but

consisting primarily of sand. In all cases, the materials are classified as poorly graded sand (SP).

When the excavation, segregation, mixing and backfilling were complete, one post-installation barrier quality assurance sample was collected for every 600 square ft of barrier surface area. Grab samples were collected using a microcore sampler driven approximately 36 inches below the pond bottom (barrier) surface. This work was conducted prior to flooding the excavation area. A total of 21 post-installation samples were collected for analysis on 01 September.

Table 4 provides average concentrations of iron and manganese in sediments (from surface to one foot), prior to barrier construction, and from post-installation barrier sediments (surface to three ft). The post-installation barrier sample results indicate that the total iron concentrations in barrier sediments are approximately 20 times greater than that in the bottom sediments prior to barrier construction.

The iron concentrations in the post-installation samples range from 13,700 mg/kg to 67,600 mg/kg. These values vary by five times, which is comparable to the variability indicated by the data collected from the mixed stockpiles. The average concentration of iron in sediments within the barrier is 41,638 mg/kg based on the 21 post-installation samples. This average concentration represents approximately four percent by weight. This value is slightly greater than the three percent ZVI by weight called for in the barrier design. Although there is some apparent variability in iron concentrations within the barrier, the concentrations of iron at the low end of the range (13,700 mg/kg) are still over six times greater than the average concentration of iron in the shoreline sediments (2,126 mg/kg) prior to mixing with ZVI. It is expected that the sediments having these lower values of iron still have sufficient iron to produce enough $Fe(OH)3$ to sequester dissolved phosphorus from groundwater. In addition, as ZVI oxidizes, it is expected that some redistribution of iron will occur with dissolution and formation of $Fe(OH)3$ coatings on nearby sand grains. This effect will dampen the variability in iron concentrations throughout the sediments within the barrier zone.

Appendix D includes a project note and laboratory analytical packages for sediments samples collected prior to barrier installation, during the mixing process, and post-installation during quality assurance samples.

4.8 BARRIER PERFORMANCE MONITORING NETWORK INSTALLATION

The locations of the permanent barrier performance monitoring network, installed by the USGS before and during the barrier construction activities, are presented in Figure 13. Installation of the monitoring network was consistent with the *Workplan* and consisted of piezometers, small interval multi-level profilers, interface diffusion chambers, horizontal multi-level samplers, and seepage meters. Placement of the monitoring equipment within the barrier at prescribed elevations was difficult due to the constant influx of water into the excavation. The constant influx increased the difficulty of establishing and maintaining elevation control. To overcome these problems, USGS staff members worked closely with the operators to ensure that the monitoring equipment was installed appropriately. Despite the difficulties, the permanent monitoring network was successfully installed. The various barrier performance monitoring devices that constitute the permanent monitoring network and the types of samples and measurements that were collected at each type of device are summarized below.

Piezometer Clusters. Two piezometer clusters were installed within the pond and one along the shoreline. The piezometer clusters were installed to allow for vertical profiling of discharging groundwater concentrations as well as an evaluation of piezometric head differences between deep piezometer screened sections and shallower screened sections. These piezometer clusters were sampled for field parameters including specific conductance, pH, dissolved oxygen, and dissolved phosphorus. Piezometric head measurements were also collected at these locations.

Small Interval Multi-Level Profilers. A total of ten multi-level profilers were installed. The small interval profilers consist of ½-inch diameter polyvinyl chloride (PVC) pipe fitted with five port holes at various depths below the pond bottom (0.0, 0.8, 1.6, 2.2, and 3.4 ft). Each port is connected to the surface by a 1/16-inch diameter polyethylene tube.

Inside each porthole, a fiberglass mesh screen is attached to the end of the interior tubing. The top of the sampler is fitted with a 4-inch diameter PVC canister 0.4 ft in length situated along the pond bottom. The purpose of this canister is to hold and protect the sample tubing as well as to protect the sampler top.

The purpose of these small interval multi-level profilers is to enable the evaluation of pore water concentrations within the barrier vertical section and beneath the barrier. Each port of the ten multi-level profilers was sampled. Field parameters including specific conductance, pH, dissolved oxygen, temperature, and dissolved phosphorus were measured. Micro-nutrients were analyzed at the USGS National Water-Quality Lab (NWQL) in Denver, Colorado for select profiles. These data are provided in Appendix E.

Interface Diffusion Chambers. A total of eight of these sampling devices were installed. Groundwater diffusion chambers were designed to be used to characterize pore water at very small vertical intervals (<0.3 ft). The diffusion chamber apparatus is a vertical wooden rack of sampling bottles, housed within a four-inch by four-inch square PVC post that is 3.0 ft in length. Each 60-milliliter sampling bottle has a 0.10-micron diffusion membrane sealing its opening. When placed in the vertical sub-pond bottom rack, the bottles are exposed to the aquifer through portholes in the PVC housing. Each sampler is filled with de-ionized water and allowed to equilibrate with the ambient groundwater. The rack can hold up to 13 sample bottles. To provide time for equilibration, the bottles are typically deployed for two to four weeks prior to sampling. The finished installation at the pond bottom consists of a flush-mounted 4-inch by 4-inch square stainless steel cap. Figure 14 provides a photograph of a multi-level drivepoint profiler and a diffusion chamber sampler prior to installation. Figure 15 shows a multi-level profiler and diffusion chamber installed.

After one month of equilibration, diffusion bottles were removed from the eight diffusion chambers. The analytes for the diffusion chambers consisted of dissolved phosphorus and specific conductance. Phosphorus concentration data from the diffusion chambers were not obtained in time to be included in this report. These data will be presented in a

future Ashumet Pond Technical Memorandum scheduled for completion in the Summer of 2005.

Horizontal Multi-Level Samplers. Two horizontal multi-level samplers were installed. Figure 16 is a photograph of the southern horizontal multi-level sampler being installed. These samplers are designed to provide multiple pore water sample ports at two depth intervals below the pond bottom (0.5 ft and 3 ft below the pond bottom surface). The devices provide 15 sampling ports equally spaced along a 43.5 ft horizontal length at each of the two depth intervals.

Each port of the two horizontal multi-level samplers was sampled and analyzed for field parameters including specific conductance, pH, dissolved oxygen, temperature, and dissolved phosphorus. Select samples were sent to NWQL for phosphorus analysis.

Seepage Meters. A total of eight seepage meters were installed. Figure 17 provides a photograph of the seepage meters installed. Each permanent seepage meter consists of the top section of a plastic barrel with a removable top and a sealing ring. The meter diameter is 22 inches. The final seepage meter installation positions the lid flush with the pond bottom. The seepage meters were designed and placed to enable the collection of discharging groundwater to the pond as well as to obtain measurements of the rate of discharge. Groundwater discharge rates and dissolved phosphorus samples were collected from the eight seepage meter locations. USGS is analyzing this data; it will be presented in future reports.

Appendix C provides additional photographs of equipment being installed in conjunction with construction activities. In general, the devices were installed as designed with the exception of:

1. A slight difference in final locations from targeted positions for some devices.
2. Multi-level profile site F645 was not permanently installed due to the position of the Aquabarriers®. (Temporary drive-point profilers may be used at this site as an alternative in the future.)

3. Instrumentation at the control site was installed using the excavator that was on-site for barrier construction.
4. One pond-bottom piezometer (MA-FSW 635P01-0010) was destroyed and the tops of two other piezometers were bent during demobilization of the Aquabarrier® bladder cofferdams. These may be repaired in the future.

In addition to the permanent monitoring instruments installed by USGS, ten temporary drive points were advanced to augment the evaluation of the area shortly after barrier installation. Refer to Section 5 for a discussion of post-installation performance monitoring results.

5.0 POST-INSTALLATION MONITORING

The following sections summarize and evaluate the post-installation barrier performance data. Figures, graphs, and tables of post-installation data collected from permanent and temporary monitoring locations are provided in Appendix E. The sampling events that were conducted as part of the initial barrier performance evaluation effort consist of the following:

- A "development" sampling event that was conducted in early September 2004, immediately following barrier installation. During this event, the USGS purged the permanent multi-level profilers and horizontal multi-level samplers to confirm that all sampling ports were operable. A limited number of pore water samples were collected from the permanent monitoring network at this time (Appendix E, Table 1).
- The primary post-installation sampling event (referred to as "Post-1") was conducted in late October/early November 2004. It was assumed that the two-month period between the completion of the barrier and the initiation of the primary sampling event was sufficient for steady state flow and geochemical conditions to be established within the barrier. During this sampling event, data were collected from permanent seepage meters, multi-level vertical and horizontal profilers and diffusion chambers (Appendix E, Tables 2 and 3).
- Ten temporary drive point locations were installed in early November 2004 within and just outside the barrier footprint. These drive points were sampled primarily to establish a data set for phosphorus concentrations (Appendix E, Table 4) in the target area that was independent of the data obtained from the permanent monitoring network. The phosphorus data obtained from the temporary drive points were used to verify that the phosphorus concentrations measured in samples from the permanent monitoring network are representative of conditions throughout the barrier.

Detailed descriptions of these three early barrier porewater sampling events and a summary of the analytical results are presented below. Data tabulations and graphical presentations are presented in Appendix E. Additional data collected during future barrier performance monitoring events will be presented in technical memoranda for the Ashumet Valley plume.

5.1 BARRIER MONITORING NETWORK – PRELIMINARY "DEVELOPMENT" PERFORMANCE RESULTS

Immediately following the installation of the barrier and the associated permanent barrier performance monitoring network (Figure 13), the USGS conducted a preliminary "development" sampling event to assess the condition of the monitoring devices. This event was conducted on 01 September 2004 and consisted of: (1) purging pore water through the permanent vertical and horizontal multi-level drive points; followed by (2) the collection of samples from the purged vertical multi-level locations for semi-quantitative field analysis of phosphorus concentrations (Table 3, Appendix E). Purge tests indicated that most of the permanent monitoring devices were in good working order. Two sampling ports, one at location F642 and one at F643, yielded an insufficient volume of pore water to collect a sample (Table 3, Appendix E). At locations F646 and F648, the shallowest sampling ports were located above the water level of the pond at the time of sampling (Table 3, Appendix E). These two shallow ports are expected to provide water samples when the water level in the pond is higher.

These preliminary "development" data indicate that immediately after installation, the barrier began to substantially reduce the phosphorus levels discharging to the pond in the target area. These preliminary data are discussed in the next section (Section 5.2) along with data collected approximately two months later, during the Post-1 sampling event.

5.2 BARRIER PERFORMANCE DATA AND EVALUATION (DEVELOPMENT AND POST-1 SAMPLING EVENTS) OCTOBER/NOVEMBER 2004

All of the data obtained from the development sampling event are presented in Table 1 of Appendix E. The data obtained during the Post-1 sampling event for the permanent vertically and horizontally arrayed sampling devices are presented in Table 2 and Table 3, respectively, in Appendix E

Figure 18 presents vertical profiles of the dissolved phosphorus concentrations measured at the vertically arrayed multi-level sampler location F646 (Figure 13) during development sampling (Dev) and during the post installation (Post-1) sampling that was

conducted approximately two months later. The phosphorus trend in Figure 18 that is denoted as “Pre”, reflects data collected from a nearby (3 ft north) temporary drive point that was installed prior to installation of the barrier. A comparison of these three phosphorus data trends illustrate that the phosphorus concentrations reaching the pond bottom decreased dramatically and progressively over time once the barrier was installed. The slightly increasing trend observed for specific conductance and the concomitant decreasing trend observed for dissolved oxygen (DO) in the Post-1 data is consistent with the reaction of the ZVI in the barrier with the oxygenated and phosphorus-impacted groundwater that passes through prior to discharge to the pond.

The data trends that were observed at location F-646 are generally typical of the data trends observed in the other vertical multi-level sampling locations that were installed in the barrier (Appendix E). With a few exceptions, the vertical multi-level data indicate that initial barrier performance is good, significantly reducing phosphorus concentrations in groundwater as it passes through the enhanced iron content barrier zone. Phosphorus concentrations that remain in pore water sampled from the shallow sampling ports are similar to typical background groundwater phosphorus concentrations. Previous work to develop a phosphorus budget for Ashumet Pond involved sampling of a well network outside the area of the phosphorus plume and concluded that 26 µg/L is a representative concentration for background phosphorus in groundwater near Ashumet Pond (AFCEE 2002a, AFCEE 2001).

Figure 19 presents data from the southern horizontal multi-level sampler, one of the two sampling arrays of this type that were installed within the barrier footprint (Appendix E). As discussed above, these samplers were designed to provide porewater sampling ports at two depth intervals (0.5 ft and 3 ft) below the pond bottom. The devices provide 15 sampling ports at each of the two depth intervals and equally spaced along a 43.5 ft horizontal, east/west transect. The first port is located 1.1 ft east of the mean shoreline (defined by mean water level) with others spaced along the remaining section. The lateral spacing between each sampling port is 2.9 ft.

The phosphorus data presented in Figure 19 illustrate that there is a dramatic reduction in phosphorus concentrations between the base of the barrier (at 3.0 ft below pond bottom) and the approximate top of the barrier (0.5 ft below pond bottom). This dramatic decrease in phosphorus concentrations between the bottom and the top of the barrier is particularly evident in sampling ports located between 20 ft and 40 ft offshore (Figure 19). Similar to the vertically arrayed multi-level samplers, DO concentrations decreased dramatically within the barrier and the data from shallow sample ports showed phosphorus concentrations similar to, or less than, background concentrations. Specific conductance data for both the 0.5 and 3 ft sampling ports provided a signature (e.g., have values over 100 us/cm) that is generally characteristic of sewage plume-impacted groundwater.

5.3 TEMPORARY DRIVE POINT SAMPLING EVENT – NOVEMBER 2004

Ten temporary drive points were installed in and adjacent to the barrier footprint between 02 and 05 November 2004 (Figure 20). These drive points were sampled for field parameters (pH, temperature, dissolved oxygen, and specific conductance) and for selected chemical constituents including dissolved phosphorus and total phosphorus (Appendix E, Table 4). Six of the drive point locations were installed within the footprint of the barrier and three were installed outside the footprint of the barrier, but within the phosphorus plume discharge area. Groundwater was collected from all drive point locations at a minimum of two depth intervals (at 1 and 3 ft below the pond bottom). Two of the drive point locations within the barrier were sampled at four depth intervals and one of the three background locations was sampled at three depth intervals.

The drive points installed outside the barrier footprint are hereafter denoted as background locations. One of the ten locations (95DP303150B) was installed close to the edge of the barrier. Consequently, the data from this location are not reliable indicators of the chemical conditions specifically inside or specifically outside of the barrier footprint. The data obtained at this location are presented in Appendix E, Table 4, but have not been used in the data evaluation. The data obtained from these ten temporary

drive point locations were intended to augment, and provide a means of validating, the barrier performance data obtained from the permanent sampling network.

The concentrations of total phosphorus in groundwater collected from the three drive point locations installed outside the barrier footprint (95DP305275B, 95DP302075A, and 95DP301025A) did not change substantially over the depth intervals that were sampled (between three ft and one ft below the pond bottom) (Figure 21). Figure 22 illustrates the changes in total phosphorus concentrations in groundwater obtained from four drive point locations installed within the barrier footprint that were sampled at depths of one and three ft below the pond bottom. The groundwater sampled at a depth of three ft at these locations contains phosphorus concentrations that are representative of the groundwater water entering the base of the barrier. The concentrations of phosphorus in groundwater sampled at each of these four locations drops to near the analytical reporting limit (by roughly two orders of magnitude) after migrating upwards through two ft of the barrier. Figure 23 illustrates the total phosphorus trends in the two drive point locations installed in the barrier that were sampled at four different depth intervals. Due to the larger number of sampling intervals in these two locations, the pattern of phosphorus removal can be illustrated in greater detail. Figure 23 suggests that almost all of the phosphorus entering the barrier (at a depth of 3 ft) is removed by the time the groundwater moves 1 foot vertically through the barrier (i.e., to a depth of 2 ft below the pond bottom).

The results of the temporary drive point investigation closely match the high levels of phosphorus removal observed in the permanent monitoring network. This agreement between the two different monitoring approaches suggests that the observed phosphorus removal is occurring throughout the footprint of the barrier and is not the result of local effects produced during, or by, the installation of the permanent monitoring network.

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6.0 OTHER POST-INSTALLATION ACTIVITIES

6.1 RESOURCE PROTECTION DOCUMENTATION

Since barrier completion, project submittals have been made to the DEP Chapter 91 program and the MHC (see Appendix A). The Chapter 91 submittal included pre- and post-barrier installation pond bathymetric surveys, as required by the permit. In a letter report to the State Archaeologist, dated 04 October 2004, Public Archaeology Laboratory (PAL) presented the findings of its oversight activities. In summary, PAL concluded "as no archeological deposits were identified, no further archeological testing is recommended for the proposed Ashumet Pond Geochemical Barrier project area." The State Archaeologist responded in a letter to AFCEE, dated 13 October 2004, agreeing with the findings and concluding that the "project is unlikely to affect significant archeological resources" and that no further MHC review would be required.

Prior to implementation of construction activities, photographs were taken of the barrier construction area and the shoreline utilized to access the area to document conditions. Photographs to document conditions following construction were taken in September 2004 (Appendix C). AFCEE will also take additional photographs in Spring 2005 to document shoreline conditions during the active growing season. These photographs will be provided to the Falmouth Conservation Commission along with a Request for Certificate of Compliance (WPA Form 8A), in accordance with the Wetlands Protection Act and regulations (Chapter 131, s. 40 and 310 CMR 10.00).

6.2 PRE- AND POST-CONSTRUCTION POND BOTTOM BATHYMETRY

As noted previously, a pre-excavation survey of the pond bottom bathymetry was performed within the barrier installation area on 19 August 2004. On 13 September 2004, a similar survey of the post-barrier installation pond bottom was completed. The survey was conducted to evaluate bathymetry after construction and to allow for comparison to pre-construction pond bathymetry. Figure 24 is a contour map showing bathymetry data from both surveys. The pre- and post-construction bathymetric survey

mapping work was conducted in accordance with the Chapter 91 permit (Permit No. 10084, 03 August 2004). The pre-and post-construction bathymetric map was attached to a cover letter dated 6 December 2004 and provided to the DEP Wetlands and Waterways staff by AFCEE (Appendix A). This map indicates that the pre-construction pond bottom bathymetry was reasonably re-established at the completion of barrier construction activities.

6.3 WETLANDS PROTECTION ACT – CERTIFICATION

In accordance with the FCC OOC (DEP Wetland File # SE 25-3004, dated 02 July 2004), the Wetlands Protection Act MGL c. 131, s. 40, 310 CMR 10.00, and the Town of Falmouth Wetlands Bylaw and Regulations, a Request for a Certificate of Compliance (WPA Form 8A) will be prepared and submitted to the FCC. AFCEE plans to complete the submittal in the Spring/Summer 2005. This will include pre- and post- construction photographs of the project area, as requested by the FCC. Once a certification is received, it will be recorded with the Barnstable County Registry of Deeds, and evidence will be provided to the FCC.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 REVIEW

In general, the construction of the barrier went smoothly. The primary issue at the time of construction had to do with inadequate pumping capacity to dewater the work area because of leakage beneath and possibly between the water-bladder cofferdams. Once a 12-inch pump was utilized in conjunction with the two 6-inch pumps originally mobilized to manage water flow in the work area, the excavation work progressed efficiently. This, and other "lessons learned" are summarized in Appendix F.

Data collected following barrier installation demonstrates that the barrier is removing elevated levels of dissolved phosphorus from groundwater before it can discharge to Ashumet Pond. Pore water at shallow depths within the barrier zone has phosphorus concentrations approaching, or less than, those expected in groundwater not impacted by the phosphorus plume. Phosphorus removal is thought to be occurring primarily through a combination of sorption and co-precipitation reactions with $Fe(OH)_3$ produced by the oxidation of ZVI. In the coming months and years, it is anticipated that additional data will further demonstrate the degree to which the groundwater plume is attenuating.

Surface water quality data will be collected at Ashumet Pond in the coming growing season and will be evaluated to determine if there has been improvement in the trophic health of the pond or if there has been reduction in the concentrations of dissolved phosphorus available to support algae growth.

7.2 SHORT-TERM BARRIER EFFECTIVENESS

Initial performance data indicate that a reduction in phosphorus concentrations of up to two orders of magnitude is occurring as water moves vertically through the barrier. The data suggests that most of the phosphorus reduction is occurring within the first foot of barrier thickness. Additional phosphorus concentration data collection, as well as groundwater flux data from seepage meters, will help to quantify actual reductions in

overall phosphorus load to Ashumet Pond. It is expected that the effectiveness of the barrier will increase with time as the surfaces of granular ZVI filings become further oxidized and the abundance of Fe(OH)3 coatings increases in the barrier.

7.3 EXPECTED LONG-TERM BARRIER PERFORMANCE

The footprint of the phosphorus geochemical barrier was designed to impact the smallest possible section of the pond bottom while still being large enough to remove a substantial phosphorus load from groundwater discharging into the pond. In addition, the barrier was sized such that the area would be great enough to accommodate moderate fluctuations in the pond stage over time while still providing significant reductions in phosphorus load. The target footprint for the barrier is generally where 1999, 2001, and 2003 sampling data indicate that phosphorus concentrations were in excess of 1,000 µg/L. This section of the plume footprint was thought to contribute the bulk of the plume-related phosphorus to the pond. The target area covers 12,000 ft^2 of the pond, extending approximately 300 ft along shore and 40 ft offshore relative to the September 2003 shoreline. The September 2003 shoreline was selected as the landward boundary of the barrier as it approximates the location of the pond shoreline at the average pond water level (44.3 ft msl) over the last 20 years.

An effective barrier lifetime of 25 years was selected as the goal for the design. This barrier lifetime was selected on the basis of previous geochemical modeling efforts that suggest that phosphorus loading to the pond may decrease substantially over the next 25 years (AFCEE 2003 and Parkhurst et al. 2003). However, these predictions may be incorrect and in order to ensure that sufficient ZVI was used, a constant annual phosphorus load of 100 kg/yr to the target area was assumed. This loading estimate, as it relates to the design, had additional conservatism since the total annual phosphorus load to the entire plume footprint (~ 100 kg) has been assigned to the subsection of the plume footprint selected as the target area for barrier placement.

Using these conservative assumptions, it was assumed that a total phosphorus load of 2,500 kg would reach the barrier over the next 25 years. If a maximum Fe:P mass

sorption ratio of nine (see Section 4.3 of the *Workplan*) is assumed, the minimum amount of ZVI that would be needed to produce a barrier with a 25 year lifetime is 22,500 kg or 49,500 lbs (approximately 25 tons). An additional engineering safety factor of 1.5 was proposed to offset the potential that the phosphorus load is higher than 100 kg/yr and for any loss of ZVI from the barrier area through erosion and redistribution of these materials over the next 25 years. This safety factor increased the total amount of ZVI to be applied to the barrier to about 74,250 lbs or 37 tons. Given the conservatism of these design assumptions, it is believed that enough iron will be available in shoreline sediments to sequester phosphorus in groundwater moving through the sediments for many years to come.

7.4 LONG-TERM MONITORING RECOMMENDATIONS

The initial performance data presented in the previous sections indicate that the barrier is effective in removing phosphorus. The post-installation sediment iron data (involving 21 samples) indicate that the iron varies in pond bottom sediment within the barrier by approximately five times. However, concentrations are expected to be sufficient throughout the barrier to result in significant reduction in discharging phosphorus from the STP phosphorus groundwater plume. It is expected that as the ZVI oxidizes producing additional $Fe(OH)_3$, the performance of the barrier will be enhanced. Future monitoring events will further characterize the performance of the barrier as the ZVI oxidizes and under varying pond stages.

It is recommended that the evaluation of the remaining data from the post-barrier installation monitoring event (Post 1), including that from the seepage meters and the interface diffusion chambers, be presented in a future Ashumet Valley report. The permanent installations, including the vertical multi-level samplers, horizontal multi-level samplers, diffusion chambers, and seepage meters offer excellent locations to continue to monitor the performance of the barrier (Figure 13). In addition, the permanent piezometer clusters provide good reference locations for evaluation of groundwater quality beneath and outside the barrier and evaluation of groundwater hydraulics.

AFCEE will work with the USGS to develop a long-term performance monitoring plan, utilizing the permanent network and additional temporary drivepoints. The next performance monitoring event will be conducted in the Summer/Fall of 2005. Future presentation of monitoring data will be incorporated into Ashumet Valley reports. Any recommended adjustments to the performance monitoring program will also be presented.

8.0 REFERENCES

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APPENDIX A

Order of Conditions, Permit And Other Post Installation Correspondence

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
INSTALLATION RESTORATION PROGRAM
OTIS AIR NATIONAL GUARD BASE, MA 02542-5028

30 July 04

HQ AFCEE/MMR
Installation Restoration Program
322 E. Inner Road
Otis ANG Base, MA 02542

Elizabeth Kouloheras, Chief
Wetland and Waterways Program
Bureau of Resource Protection
Department of Environmental Protection
20 Riverside Drive
Lakeville, MA 02347
(**Sent Via Facsimile**)

Dear Ms. Kouloheras

The Air Force Center of Environmental Excellence (AFCEE), is pleased to provide final details of project activities and minor permit clarifications relating to the Ashumet Pond Geochemical Barrier Project, as discussed Thursday (July 29th) with Jim Mahala and Dave Hill of your office by Spence Smith of CH2M HILL. We are in the final stages of planning and preparations to mobilize the project to the field on **Monday, August 9th**.

In making final changes to our field workplans, we determined that a few items of clarification relating to the project should be communicated to the Department. In discussions with the permitting staff the items were deemed <u>not</u> to change the conditions specified in the Section 401 Water Quality Certification (dated July 21, 2004) and the draft Chapter 91 Permit (to be issued shortly) and it was determined that to close the loop we would follow-up with a letter summarizing the items discussed. The items are as follows:

- The estimated dredge volume in the 401 Water Quality Certification is listed as 440 cubic yards and should be 1334 cubic yards. The smaller number relates a subarea volume.

- In response to the environmental review by the Natural Heritage and Endangered Species Program (NHESP), the total length of the silt curtain and the enclosed area were reduced. This was to ensure that sandy-bottom habitat for State-listed species of Special Concern, Tidewater Mucket (*Leptodea ochracea),* is not contained within the contained area. A letter response to the NHESP with maps showing these changes was provided to the Department . The revised silt curtain configuration indicated in the figures is being incorporated into our final workplan.

- In the draft workplan and other information provided with our 401 Water Quality Certification (transmittal W052113) and Chapter 91 Permit (transmittal W052106) applications we indicated that we would accomplish the dewatering, excavation, sediment mixing with iron filings, and sediment placement project, involving a 300′ by 40′ total area, in three sequential subareas of 100′ by 40′. After further planning and

review, we desire the flexibility to make a field determination as to optimal size of the subareas to be contained within the aquabarriers, dewatered and sediment excavated/mixed/placed and restored. If possible the full area would be contained within the aquabarriers rather than three subareas to simplify logistics; however, we desire the flexibility to determine if one, two, or three dewater/excavation areas will be needed to complete the project. The total work area and resource protection measures, involving aquabarriers and enclosing silt curtain remain unchanged.

- The United States Geological Survey (USGS) has recently developed a pre- and post-barrier installation monitoring scheme such that AFCEE will obtain data to best characterize and demonstrate the geochemical barrier's effectiveness. This involves the use and removal of a number of temporary monitoring devices prior to barrier installation to develop baseline data and the installation of a small number of monitoring devices concurrent with barrier installation that will remain to monitor performance. These consist of diffusion chambers, seepage meters, multilevel samplers, and drive points. The attached figure depicts the location of these devices within the 40' by 300' barrier footprint area. All the devices are either buried within the geochemical barrier layer or monitor zones above and below the barrier layer. The pond bottom penetrations of the devices are either flush with or only slightly above the pond bottom and do not present obstructions. Two horizontal multilevel samplers buried in the sediments will have two flush mount locking boxes on the adjoining shoreline for access to sampling ports.

The AFCEE team has enjoyed working with your staff to develop and move this project along through the permitting process. We look forward to completing the field implementation portion of the project and to bring the desired reductions in the dissolved phosphorus load in Ashumet Pond. If you have any questions or require additional information, please to not hesitate to give me a call at (508) 968-4670 ext 4952 or call our consultant (CH2M HILL) contact, Spence Smith (617) 523-2002 ext. 268.

Sincerely

JONATHAN S. DAVIS
Remediation Program Manager

Attachment:
USGS Monitoring Workplan – Figure 5

cc:
United States Geological Survey (Denis LeBlanc, Tim McCobb)
Falmouth Conservation Commission (Peggy Emslie)
MA DEP (Len Pinaud, Jim Mahala, David Hill)
US EPA (Paul Marchessault)
CH2M HILL (Spence Smith, Jon Blount)
ECC (B. G. Chabot)

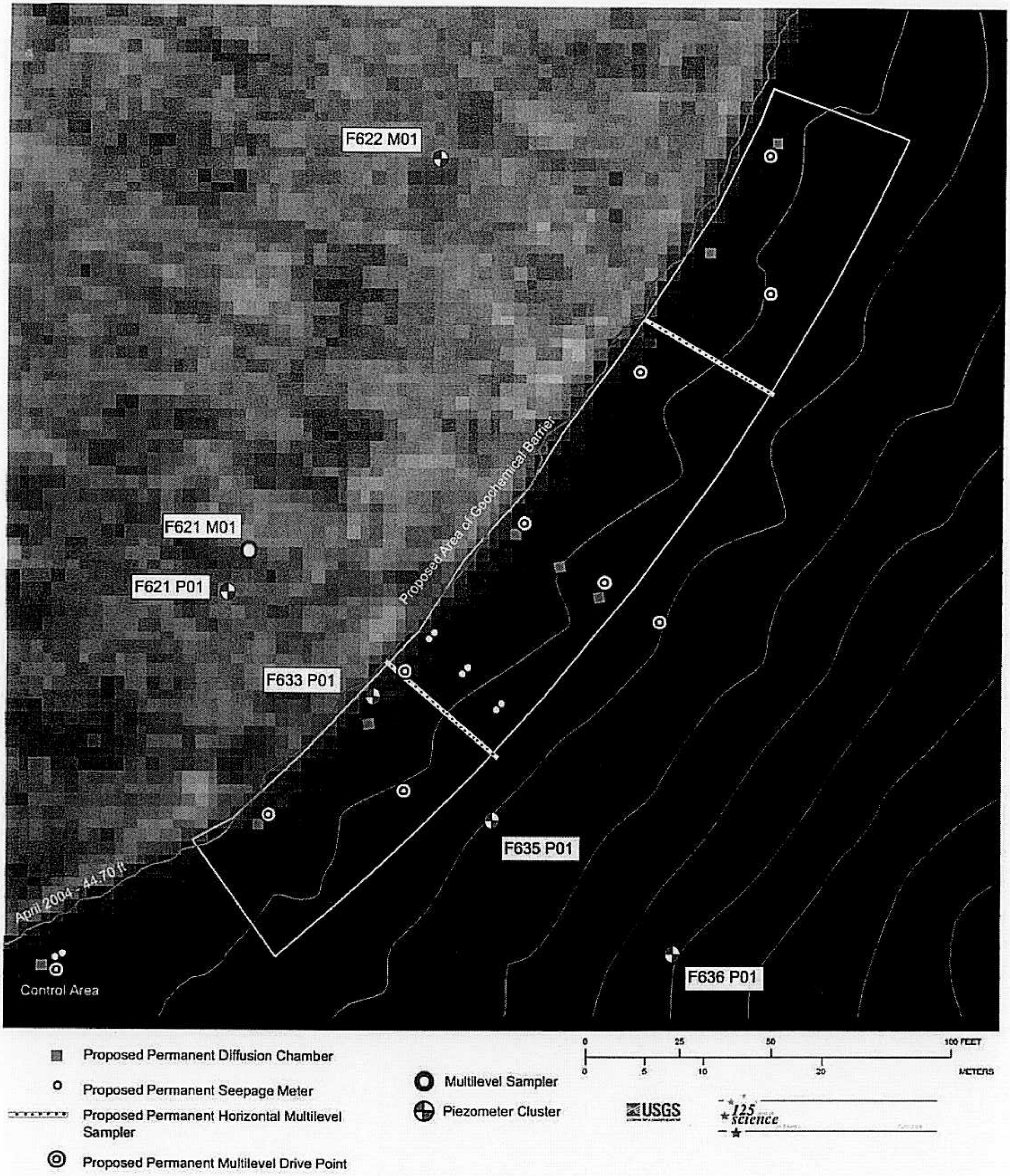


Figure 5. Proposed permanent seepage meters, multilevel drive points, horizontal multilevel samplers, and diffusion chamber locations. (Total seepage locations = 4, total multilevel drive points = 8, total MLS lines = 2 (coupled), total diffusion chamber locations = 8).

PAL

October 4. 2004

Brona Simon
Massachusetts Historical Commission
220 Morrissey Boulevard
Boston, Massachusetts 02125

Attn: Margo Muhl Davis

Re: Ashumet Pond Geochemical Barrier Project
Archaeological Monitoring
PAL #1690. MHC #RC.35161

Dear Ms. Simon:

PAL has completed archaeological monitoring of the Ashumet Pond Geochemical Barrier Project area located in Falmouth, Massachusetts (Figure 1). The Massachusetts Historical Commission (MHC) (B. Simon letter to Frank Adinolfi, Jr. dated June 11. 2004) and the Massachusetts Board of Underwater Archaeological Resources (MBUAR) (V. Mastone letter to Frank Adinolfi, Jr. dated June 3. 2004) requested that a qualified archaeologist monitor the excavation of pond sediments required as part of the project. The purpose of the monitoring was to identify and document any previously unknown cultural resources, particularly Native American archaeological sites that may be impacted by the proposed project.

The archaeological monitoring was completed between Tuesday, August 24 and Monday, August 30. 2004 utilizing the methodology outlined in PAL's Scope of Services for this project. PAL archaeological staff included Holly Herbster and Mark Lance.

The project involves the installation of a geochemical barrier within the bottom sediment in a 12,000 square foot section of the pond located 40 feet offshore. The project includes the installation of temporary aquabarrier cofferdams; the temporary removal of pond water within the work area: and the removal, screening, mixing and replacement of the pond sediments (Figure 2). A temporary staging area was established on the shoreline at an existing public boat ramp, and all heavy equipment was moved to and from the shoreline on a mat system (Figure 3).

210 Lonsdale Avenue
Pawtucket, RI 02860
TEL 401.728.8780

A PAL archaeologist was present during all periods of excavation within the dewatered project area. No indications of archaeological materials (e.g. stone tools, pottery sherds) or features (e.g. soil stains, burnt rocks) were noted during the fieldwork. **As no archaeological deposits were identified, no further archaeological testing is recommended for the proposed Ashumet Pond Geochemical Barrier project area.**

If you have any questions or require additional information, please do not hesitate to call Holly Herbster, Project Archaeologist, or me at your convenience.

Sincerely,

Deborah C. Cox

Deborah C. Cox, RPA
President

/kf

Enclosure

cc: BG Chabot, Environmental Chemical Corporation (w/ encl.)
Frank Adinolfi, Jr., AFCEE (w/ encl.)

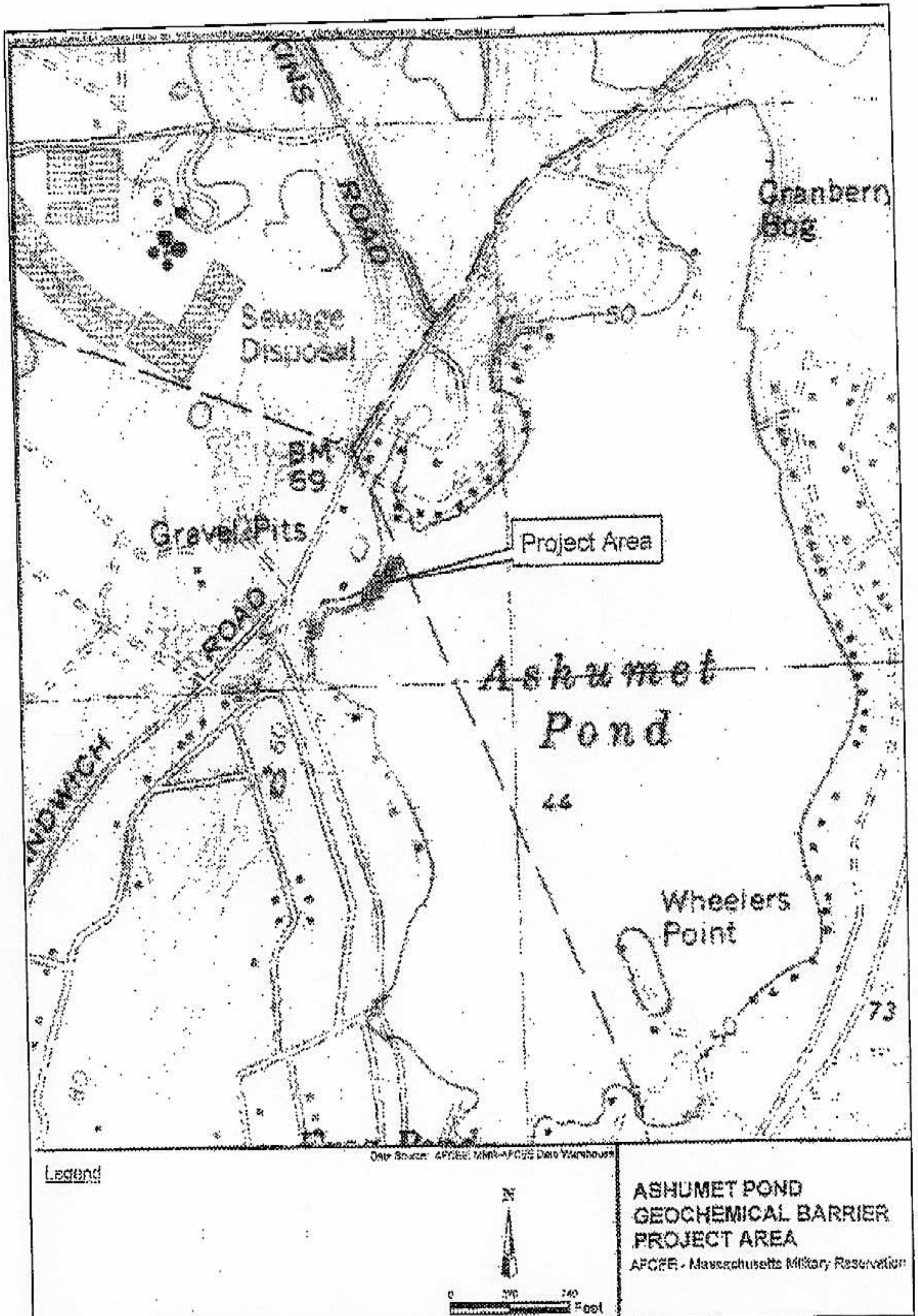


Figure 1. Location of the Ashumet Pond Geochemical Barrier Project area on the Falmouth, MA USGS topographic map, 7.5 minute series.

Figure 2. Temporary soil stockpile, Ashumet Pond Geochemical Barrier project area, looking southwest.

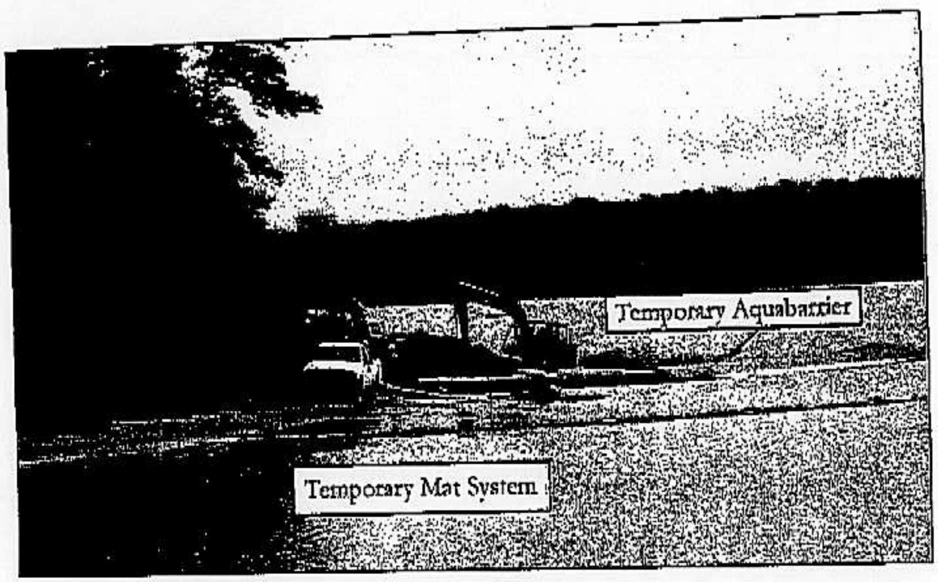


Figure 3. Temporary aquabarrier cofferdams and mat system, looking northeast from boat ramp area.

The Commonwealth of Massachusetts

William Francis Galvin, Secretary of the Commonwealth
Massachusetts Historical Commission

October 13, 2004

Frank J. Adinolfi, Jr.
AFCEE
Massachusetts Military Reservation
322 East Inner Road
PO Box 41
Otis ANG Base, MA 02542-5028

RE: Ashumet Pond Geochemical Barrier Project, Falmouth, MA. MHC #RC.35161. PAL #1690.

Dear Mr. Adinolfi:

MHC staff have reviewed the completion memorandum, received in this office October 6, 2004, regarding the archaeological monitoring conducted by PAL for the project referenced above and have the following comments.

The monitoring did not identify any archaeological materials. MHC has determined that the proposed project is unlikely to affect significant historic or archaeological resources. No further MHC review is required for this project in compliance with Section 106 of the National Historic Preservation Act of 1966 as amended (36 CFR 800) and Massachusetts General Laws, Chapter 9, Sections 26-27C as amended by Chapter 254 of the Acts of 1988 (950 CMR 71). If you have any questions, please feel free to contact Margo Muhl Davis, Archaeologist/Preservation Planner, at this office.

Sincerely,

Brona Simon

Brona Simon
State Archaeologist
Deputy State Historic Preservation Officer
Massachusetts Historical Commission

xc:
Victor Mastone, Massachusetts Board of Underwater Archaeological Resources
DEP-SERO
THPO Wampanoag Tribe of Gay Head (Aquinnah)
Glenn Marshall, Mashpee Wampanoag Tribal Council, Inc.
Jim Peters, Massachusetts Commission on Indian Affairs
Deborah Cox, PAL

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
INSTALLATION RESTORATION PROGRAM
OTIS AIR NATIONAL GUARD BASE, MA 02542-5028

15 October 2004

HQ AFCEE/MMR
322 East Inner Road, Box 41
Otis ANG Base, MA 02542-5028

Mr. Victor T. Mastone, Director
Massachusetts Board of Underwater Archaeological Resources
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
Boston, MA 02114-2119

RE: Ashumet Pond Geochemical Barrier Project, Falmouth, MA. MHC #RC.35161.

Dear Director Mastone

This is to notify you that the Air Force Center for Environmental Excellence (AFCEE) has received the final report from the Public Archaeology Laboratory on the archaeological monitoring you requested of the above subject. A copy is attached.

No archaeological deposits were identified during the monitoring. The report recommended no further archaeological testing for the project area. AFCEE will not pursue further archaeological testing in the project area.

During the project, a mat system, requested by the Massachusetts Historical Commission, was used to protect the pond banks and equipment travel ways.

If you have any questions, please contact me at (508) 968-4670, extension 5983 or frank.adinolfi@brooks.af.mil.

Sincerely

Frank J. Adinolfi Jr

FRANK J. ADINOLFI, JR.
American Indian Affairs Coordinator

Attachment:
PAL Report

cc:
Ms. Cheryl Andrews-Maltais, THPO, Wampanoag Tribe of Gay Head (Aquinnah), w/attach
Mr. Glenn Marshall, Mashpee Wampanoag Tribal Council, Inc., w/attach
Mr. Jim Peters, Massachusetts Commission on Indian Affairs, w/attach
Mr. Mark Harding, SMB, w/attach
HQ AFCEE/MMR (Mr. Davis, Mr. Minior, Mr. Karson, Mr. Byers), w/o attach

Ash. file, Frank Lana

The Commonwealth of Massachusetts

Executive Office of Environmental Affairs

251 Causeway Street, Suite 900

Boston, Massachusetts 02114-2119

BOARD OF UNDERWATER ARCHAEOLOGICAL RESOURCES

OCT 2004

RECEIVED

Tel. (617) 626-1000
Fax (617) 626-1181
http://www.magnet.state.ma.us/envir

October 22, 2004

Frank J. Adinolfi, Jr.
AFCEE
Massachusetts Military Reservation
322 East Inner Road
P.O. Box 41
Otis ANG Base, MA 02542-5028

RE: Ashumet Pond Geochemical Barrier Project, Archaeological Monitoring, Public Archaeology Laboratory, Inc. (PAL #1690, MHC #RC.35161)

Dear Mr. Adinolfi:

The staff of the Massachusetts Board of Underwater Archaeological Resources has reviewed the above referenced memorandum from PAL regarding the archaeological monitoring of the excavation of pond sediments as part of the Ashumet Pond Geochemical Barrier Project in Falmouth.

The Board is satisfied with both the methodology of the monitoring and the results that no archaeological deposits were identified. The Board has concluded that the project is unlikely to impact significant submerged cultural resources and concurs with the recommendation that no further archaeological testing for the project area is necessary.

The Board appreciates the opportunity to review and comment on this proposed project. Should you have any questions regarding this letter, please do not hesitate to contact me at the address above, by email at victor.mastone@state.ma.us or by telephone at (617) 626-1141.

Sincerely,

Victor T. Mastone
Director

Cc: Brona Simon, MHC
Deborah Cox, PAL
Jim Peters, MA Commission on Indian Affairs

Rec'd 12/14/04

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
INSTALLATION RESTORATION PROGRAM
OTIS AIR NATIONAL GUARD BASE, MA 02542-5028

6 December, 2004

HQ AFCEE/MMR
322 East Inner Road
Otis ANGB, MA 02542-5028

Mr. Dave Hill
Wetlands and Waterways Program, Chapter 91
Department of Environmental Protection
20 Riverside Drive
Lakeville, MA 02347

Dear Mr. Hill

The Air Force Center for Environmental Excellence (AFCEE) is submitting this surveyed plan in accordance with Standard Condition #7 and Special Condition #6 of our Waterways permit #10084 issued, August 3, 2004. This permit was associated with the Ashumet Pond Geochemical Barrier Project in Falmouth, MA. The attached survey plan of pond bottom bathymetry shows the elevation of the pond bottom on August 19, 2004 prior to the initiation of zero-valent iron mixing with shoreline sediments and on September 13, 2004, following completion of the work. Initial field data indicate that the project is successful in removing dissolved phosphorus in groundwater entering the pond ecosystem. Slight differences in the before and after bathymetry are expected to smooth out during the winter months in this shallow (0-3 foot depth) shoreline environment.

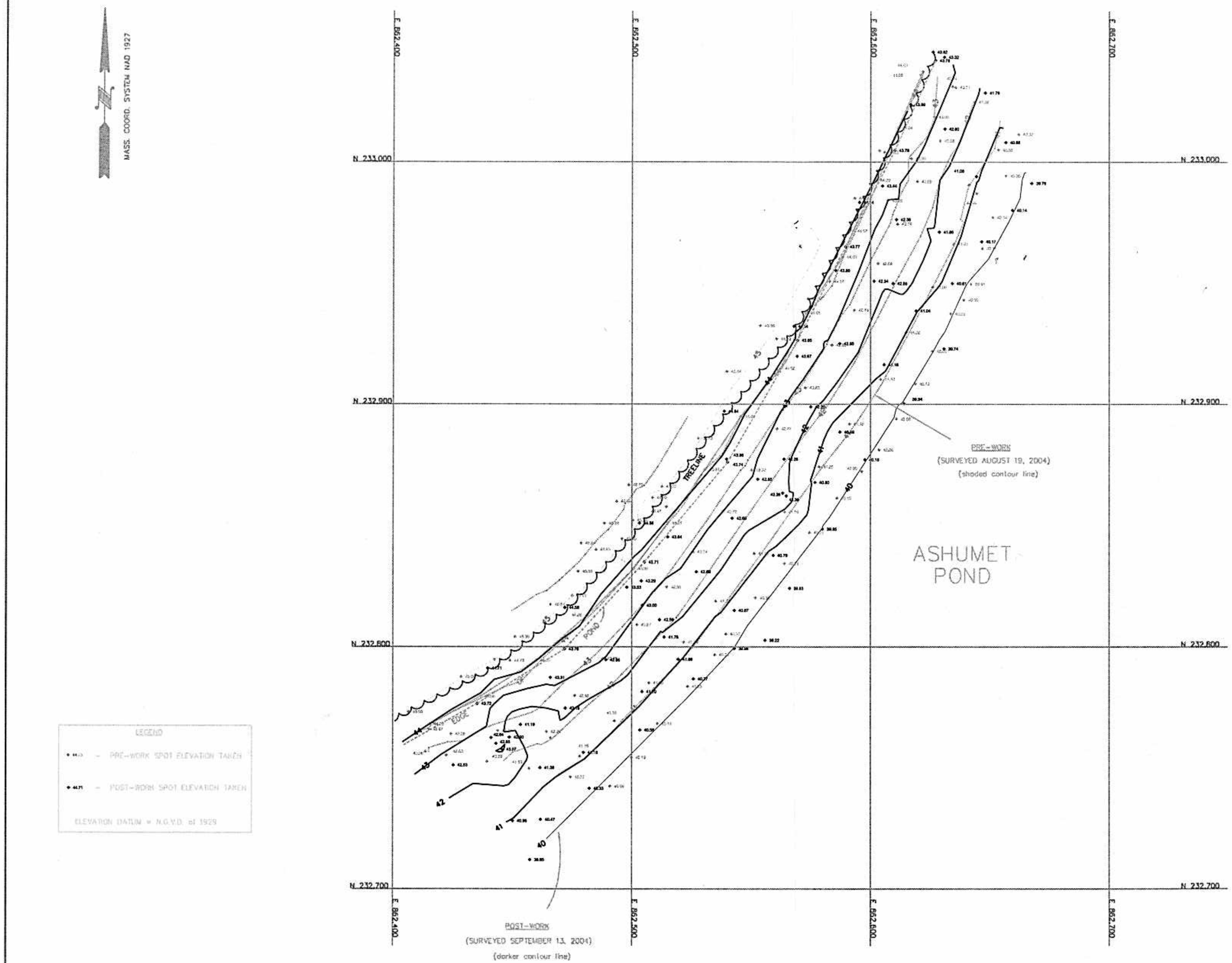
Ashumet Pond Phosphorus Geochemical Barrier installation work is complete and monitoring is underway. We are submitting this surveyed plan within the required 90 day period following completion of construction. If you have questions or require additional information, please contact me at (508) 968-4670 x 4952.

Sincerely

JONATHAN S. DAVIS, P.E.
Remediation Program Manager

1 Attachment:
Pre & Post Existing Conditions of Ashumet Pond

cc:
MA DEP SERO
Dave Keddell, US Army Corps of Engineers
Steve Hurley, MA Fisheries and Wildlife
J. Davis, M. Minior, AFCEE/MMR
B. Chabot, ECC
M. Slechta, J. Blount, S. Smith, CH2M Hill
L. Brodziak Portage



PRE & POST
EXISTING CONDITIONS
PLAN OF LAND
OF
ASHUMET POND
IN
FALMOUTH, MASS.

SCALE: 1"=20'   AUGUST 20, 2004   REVISED 9/13/04 10/25/04

NORWOOD ENGINEERING CO., INC.
CONSULTING ENGINEERS - LAND SURVEYORS
1410 ROUTE ONE   95 STATE ROAD
NORWOOD, MA 02062   SAGAMORE BEACH, MA 02562

METERS 0 5 10 20
FEET 0 10 20 40 60

6042-03

604203TOPO3.DWG (604203topo.crd)

APPENDIX B

Pre-Installation Groundwater Analytical Data

Ashumet Pond Geochemical Barrier for Phosphorus Removal
Pre-Installation Field Monitoring Results
U.S. Geological Survey

Pre-Installation Baseline Monitoring

Temporary Drive-Point Sampling (June 29 – July 2, 2004)
(**figs. 1, 2, 3; table 1**)
Temporary Vertical Multilevel Drive-Point Profiles (July 20-23, 2004)
(**figs. 4, 5 a,b,c; table 2**)

List of Figures

List of Tables

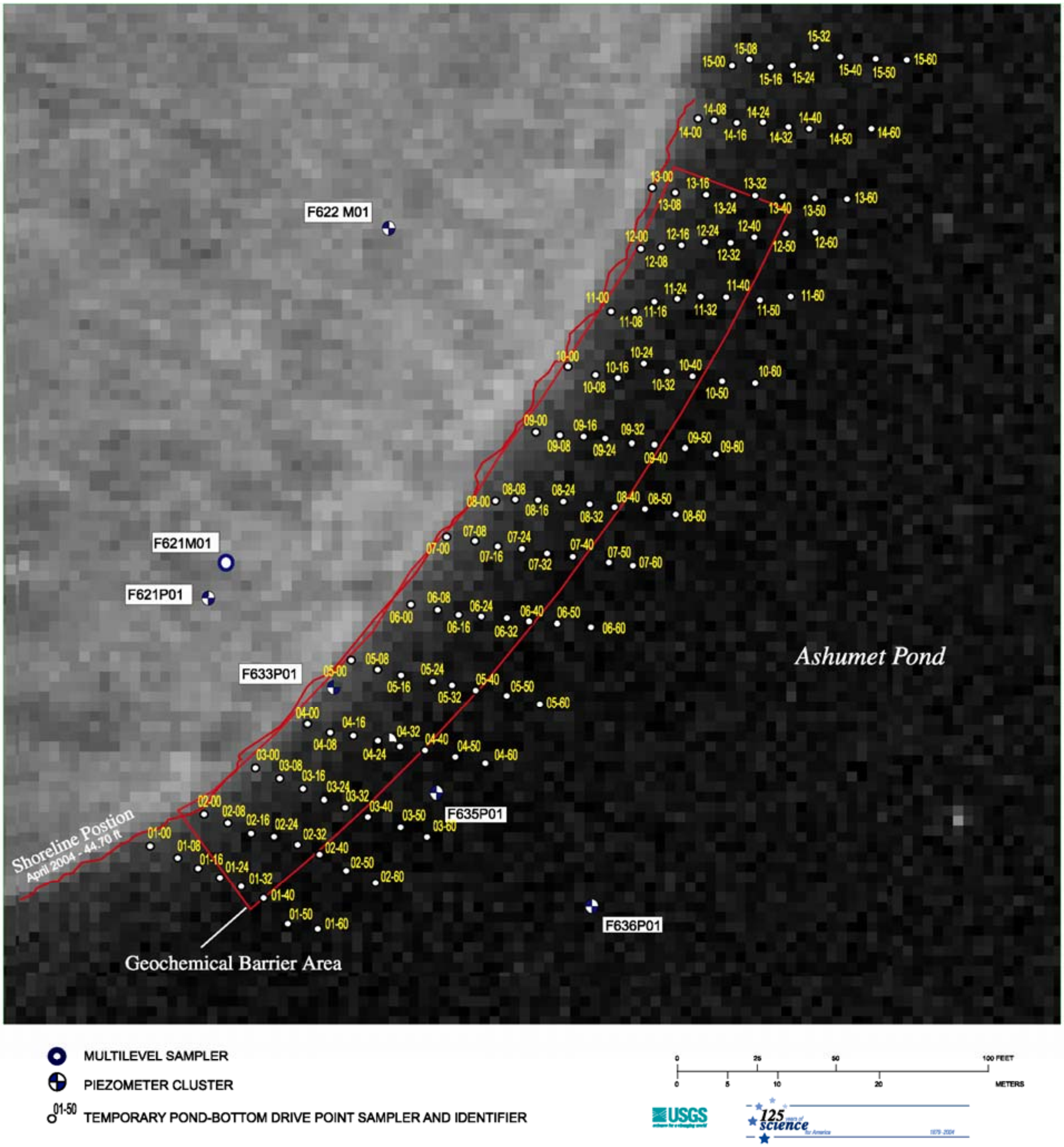


Figure 1. Locations of temporary drive points installed and sampled on June 29 - July 2, 2004, to delineate the phosphorus discharge area.

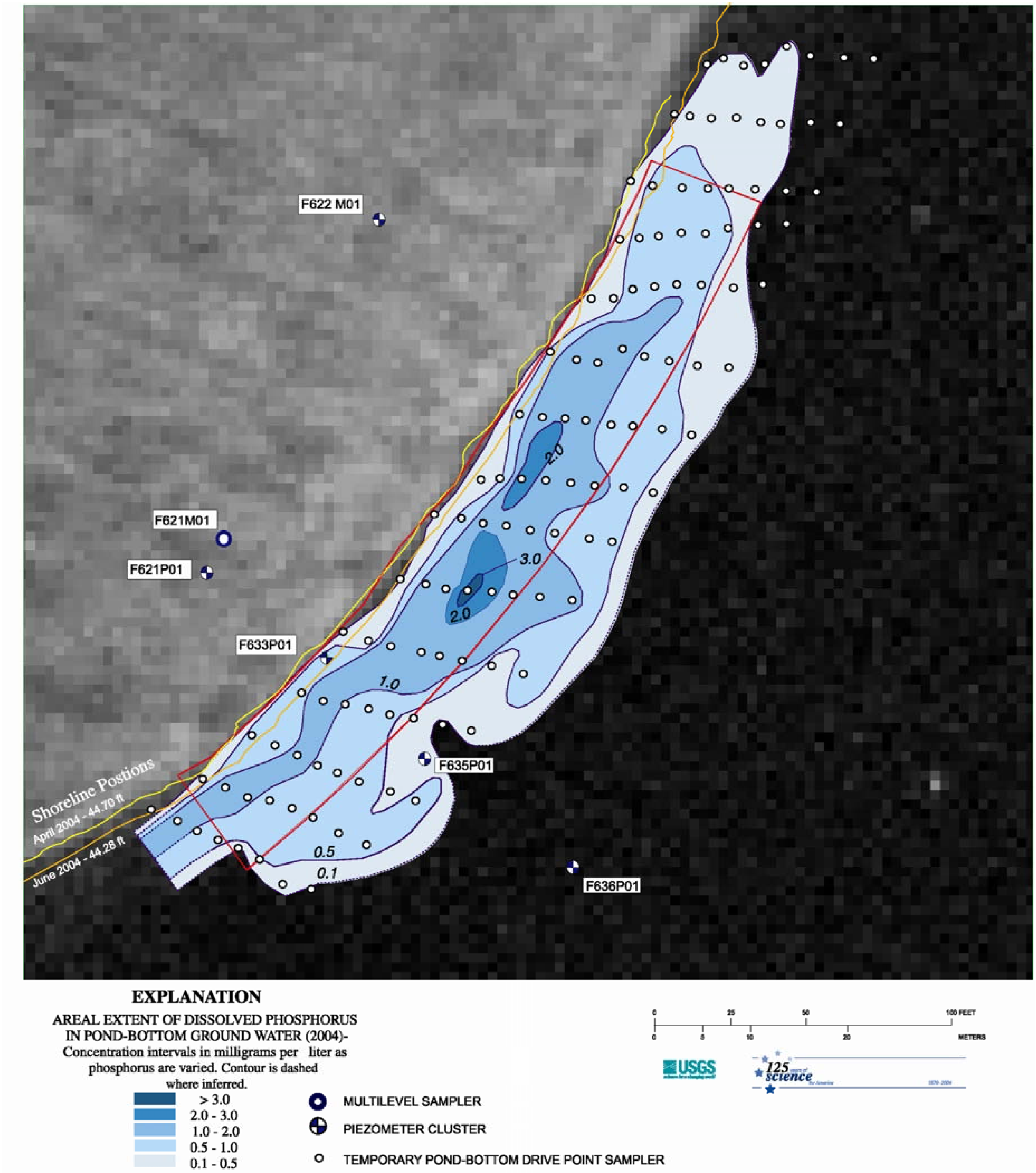


Figure 2. Areal distribution of dissolved phosphorus in pond-bottom ground water in the proposed geochemical barrier area, Ashumet Pond, Massachusetts, June 29 - July 2, 2004.

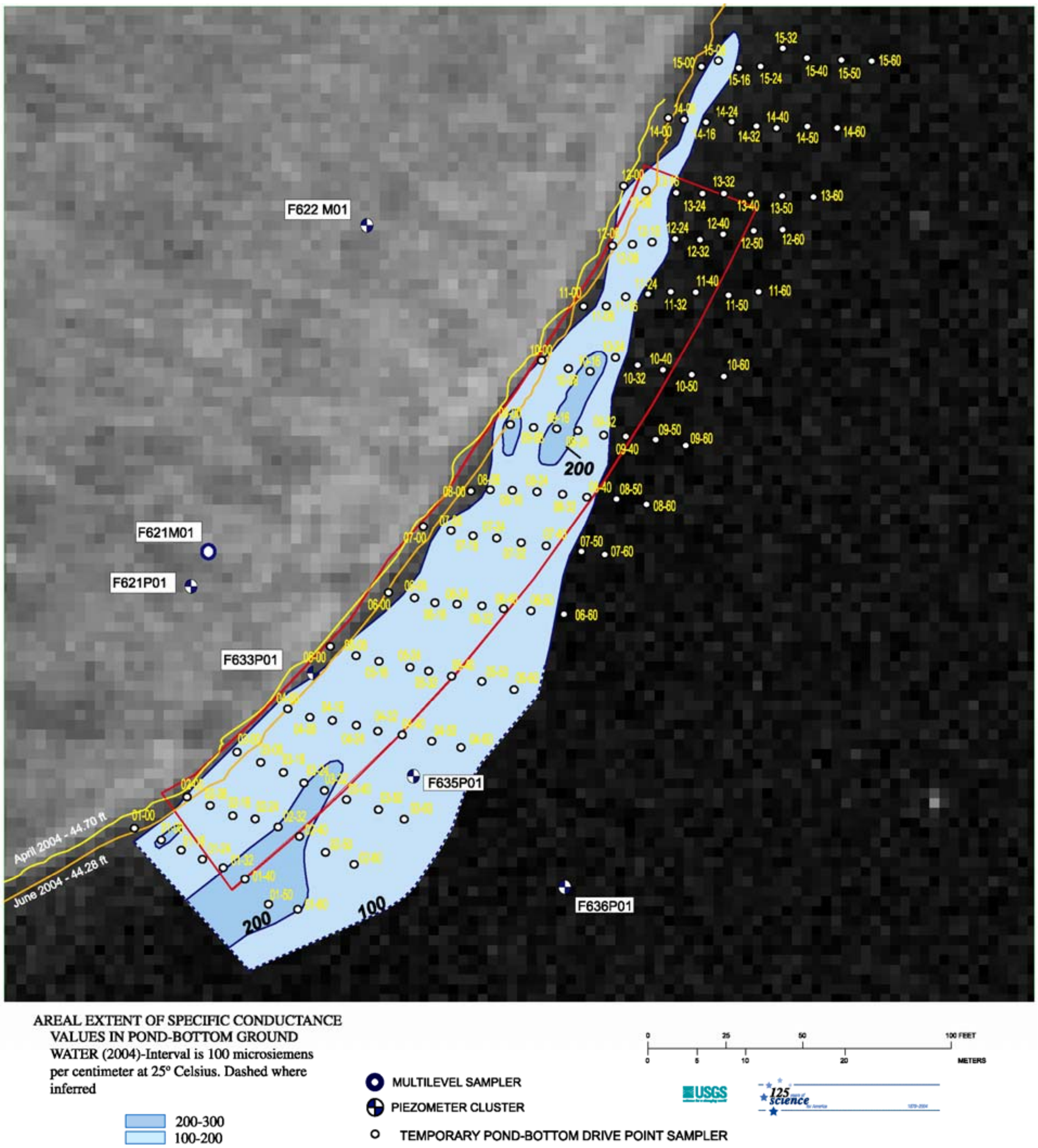


Figure 3. Areal distribution of specific conductance in pond-bottom ground water in the proposed geochemical barrier area, Ashumet Pond, Massachusetts, June 29 - July 2, 2004

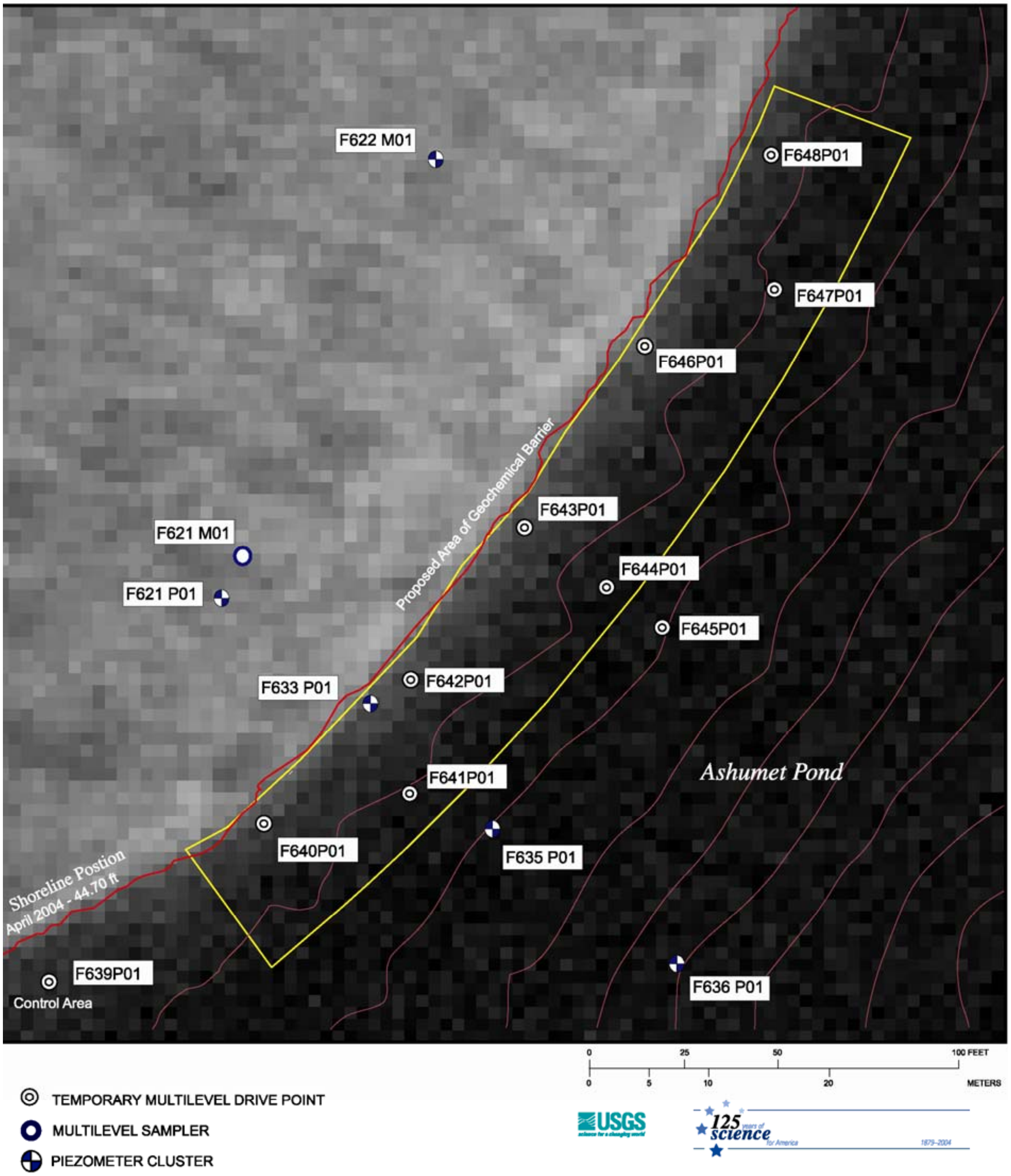


Figure 4. Locations of temporary multilevel drive point locations measured during the week of July 19, 2004, prior to barrier installation. (Total multilevel drive points = 10).

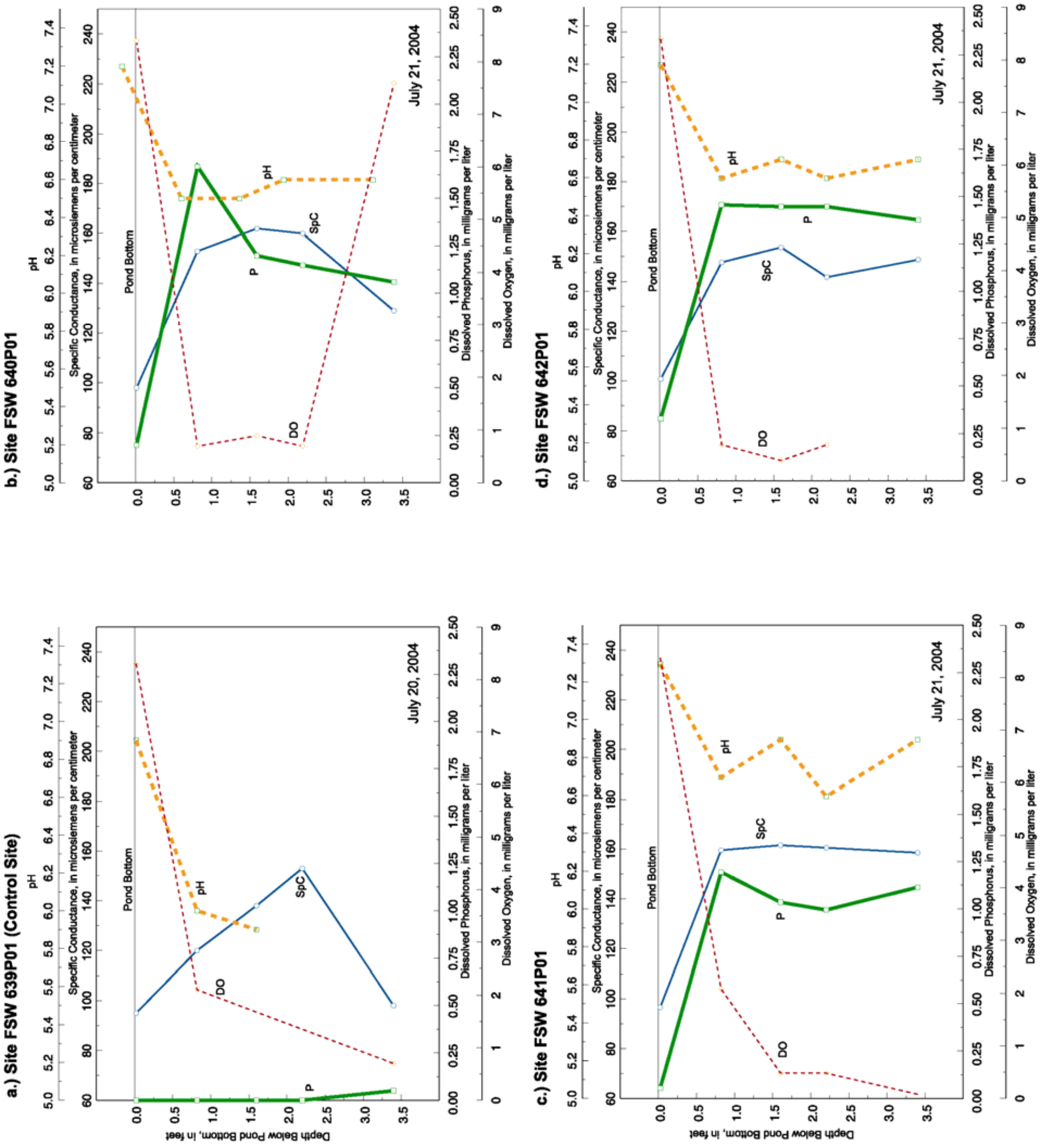


Figure 5. Geochemical profiles from temporary pond-bottom multilevel drive-point samplers prior to installation of the geochemical barrier (page 1 of 3).

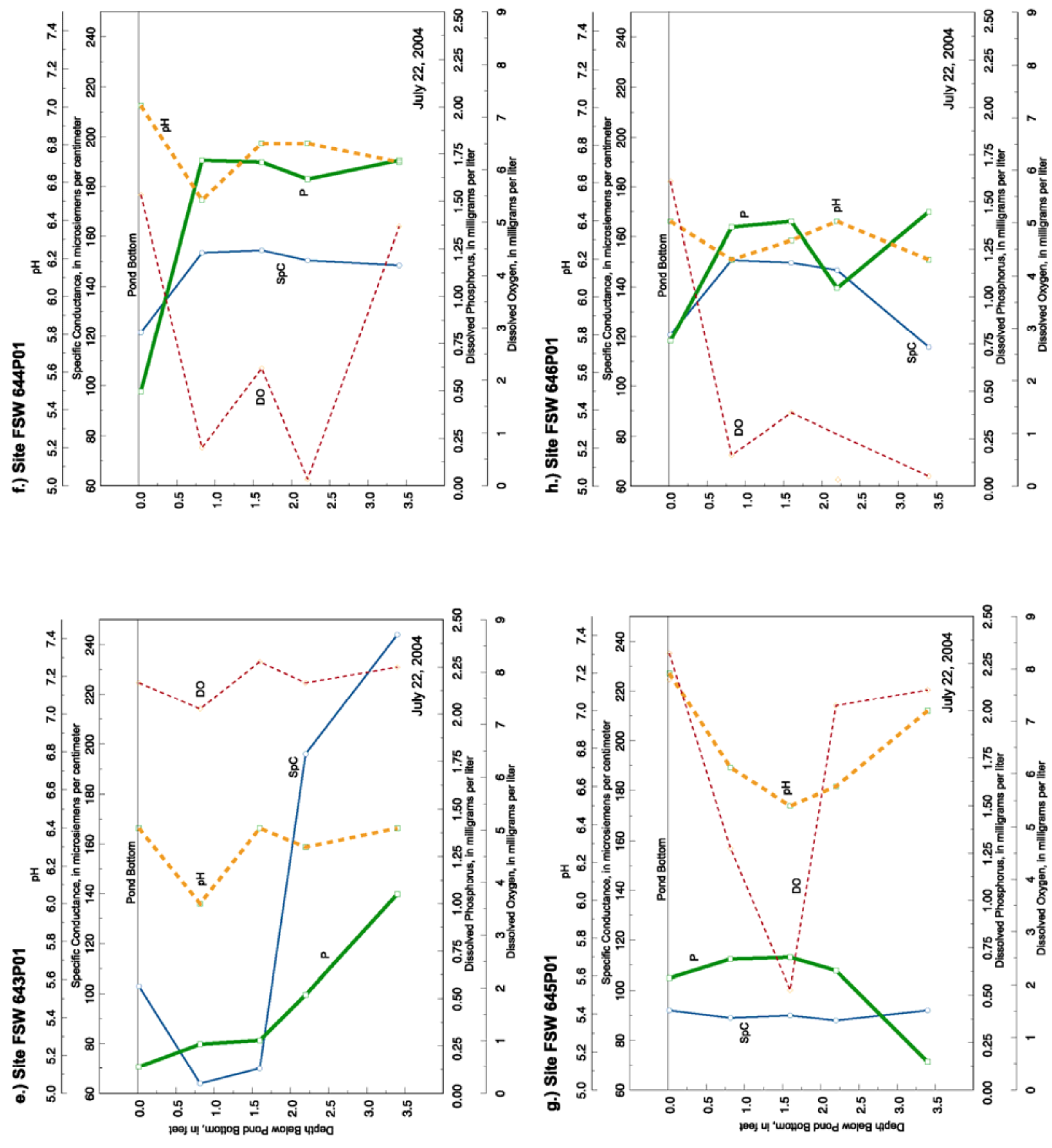


Figure 5. Geochemical profiles from temporary pond-bottom multilevel drive-point samplers prior to installation of the geochemical barrier (page 2 of 3).

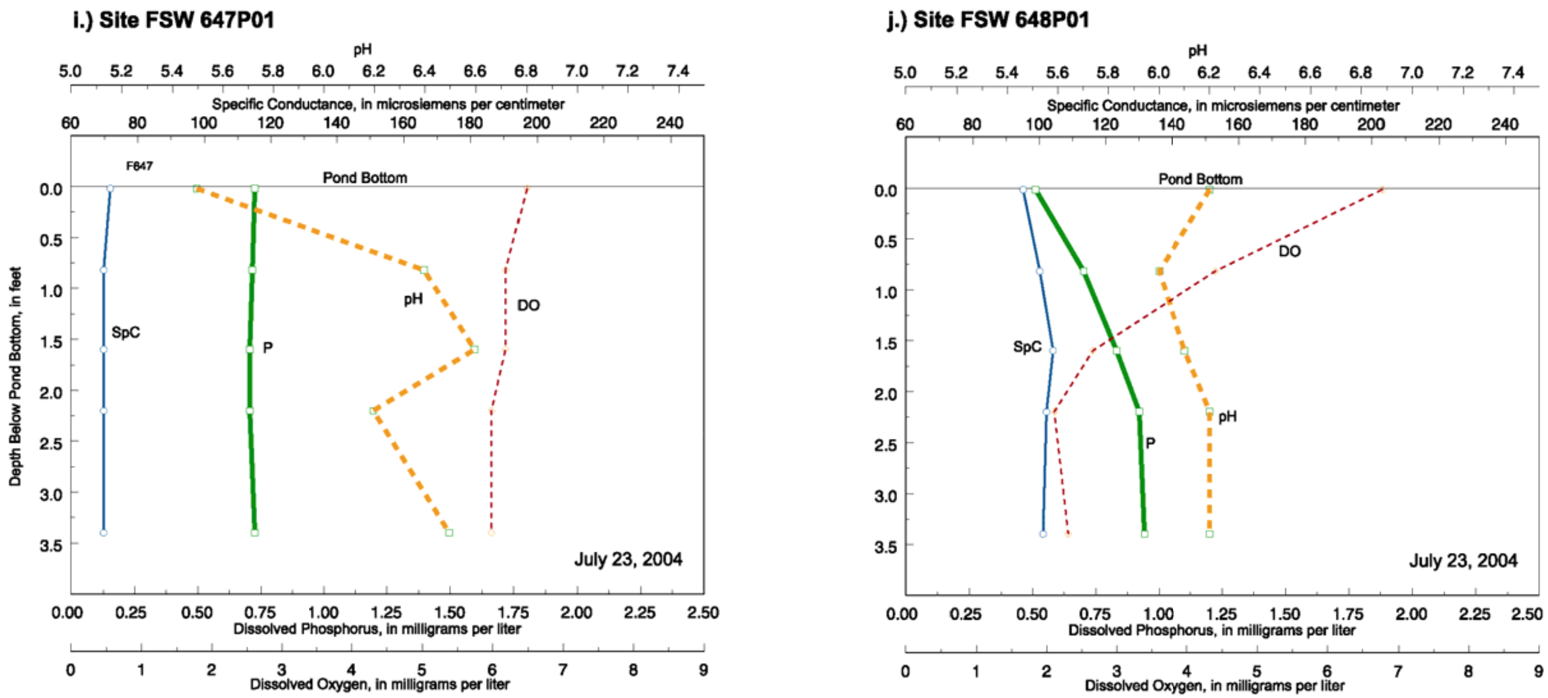


Figure 5. Geochemical profiles from temporary pond-bottom multilevel drive-point samplers prior to installation of the geochemical barrier (page 3 of 3).

Table 1. Location data and field chemical analyses of ground-water samples collected from a temporary drive point below the pond bottom, Ashumet Pond, June 29 - July 2, 2004

[State plane coordinates were determined using global positioning system from North Atlantic Datum 1983 (NAD83). Coordinates were projected to North Atlantic Datum 1927 (NAD27) using a Geographical Information System (GIS).
Altitude is in feet relative to the National Geodetic Vertical Datum of 1929 (NGVD29). m, meters; ft, feet; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter. Drive-point method: KV, KV Associates "macho sampler".
Pond stage determined by measurement of USGS pond siphon gage located near the Fishermans Cove boat ramp. Dissolved oxygen (less than 2 mg/L) and field phosphorus were determined onsite using a colorimetric photometer. Dissolved oxygen greater than 2 mg/L was not determined.]

USGS Location ID	NAD83 Easting (m)	NAD83 Northing (m)	NAD27 Easting (ft)	NAD27 Northing (ft)	Date Sampled	Distance from Shore (ft)	Pond Stage (ft above NGVD29)	Water Depth (ft)	Drive-Point Method	Drive Length (ft)	Alt. Bot. of Drive Point (ft above NGVD29)	Specific Conductance (µS/cm)	Temp (°C)	Oxygen, dissolved (mg/L)	Field Phosphorus, dissolved (mg/L as P)
01-00	280031.560	820965.933	862433.799	232782.837	06/29/04	0	44.28	0.00	KV	3.0	41.28	67.2	14.7	>2.00	0.00
01-08	280034.369	820964.705	862443.015	232778.808	06/29/04	8	44.28	0.50	KV	3.0	40.78	205.0	21.9	>2.00	1.52
01-16	280036.304	820963.762	862449.364	232775.714	06/29/04	16	44.28	1.15	KV	3.0	40.13	144.0	20.9	>2.00	0.95
01-24	280038.567	820962.851	862456.788	232772.725	06/29/04	24	44.28	1.50	KV	3.0	39.78	146.0	20.4	0.500	0.75
01-32	280040.713	820961.939	862463.829	232769.733	06/29/04	32	44.28	1.85	KV	3.0	39.43	188.0	19.4	0.215	0.11
01-40	280042.844	820960.887	862470.820	232766.281	06/29/04	40	44.28	2.35	KV	3.0	38.93	214.0	19.3	0.300	0.54
01-50	280045.233	820958.198	862478.658	232757.459	06/29/04	50	44.28	3.00	KV	3.0	38.28	221.0	19.4	0.075	0.46
01-60	280048.219	820957.678	862488.455	232755.752	06/29/04	60	44.28	3.60	KV	3.0	37.68	204.0	19.1	0.100	0.07
02-00	280037.027	820969.126	862451.736	232793.312	06/29/04	0	44.28	0.00	KV	3.0	41.28	104.0	18.8	>2.00	0.15
02-08	280039.218	820968.237	862458.924	232790.396	06/29/04	8	44.28	0.50	KV	3.0	40.78	147.0	19.1	0.055	1.55
02-16	280041.612	820967.250	862466.778	232787.157	06/29/04	16	44.28	1.10	KV	3.0	40.18	133.0	19.9	0.185	1.04
02-24	280043.836	820966.903	862474.075	232786.019	06/29/04	24	44.28	1.65	KV	3.0	39.63	163.0	16.7	>2.00	0.77
02-32	280046.169	820966.134	862481.729	232783.495	06/29/04	32	44.28	2.10	KV	3.0	39.18	196.0	17.1	0.025	0.77
02-40	280048.368	820965.103	862488.944	232780.113	06/29/04	40	44.28	2.55	KV	3.0	38.73	214.0	19.2	0.150	0.69
02-50	280050.988	820963.511	862497.540	232774.889	06/29/04	50	44.28	3.20	KV	3.0	38.08	189.0	19.3	0.275	0.65
02-60	280053.917	820962.302	862507.149	232770.923	06/29/04	60	44.28	3.95	KV	3.0	37.33	180.0	20.1	0.250	0.54
03-00	280042.083	820973.687	862468.324	232808.276	06/29/04	0	44.28	0.00	KV	3.0	41.28	109.0	16.6	>2.00	0.90
03-08	280044.459	820972.572	862476.119	232804.618	06/29/04	8	44.28	0.55	KV	3.0	40.73	148.0	15.2	0.470	0.52
03-16	280046.814	820971.698	862483.846	232801.750	06/29/04	16	44.28	1.25	KV	3.0	40.03	141.0	17.1	0.240	1.17
03-24	280048.869	820970.616	862490.588	232798.200	06/29/04	24	44.28	1.65	KV	3.0	39.63	174.0	17.4	0.430	0.90
03-32	280051.055	820969.737	862497.760	232795.316	06/29/04	32	44.28	2.15	KV	3.0	39.13	208.0	16.2	>2.00	0.72
03-40	280053.234	820968.834	862504.909	232792.353	06/29/04	40	44.28	2.70	KV	3.0	38.58	178.0	19.2	0.395	0.69
03-50	280056.391	820967.845	862515.266	232789.108	06/29/04	50	44.28	3.40	KV	3.0	37.88	192.0	18.0	0.575	0.47
03-60	280059.026	820966.840	862523.911	232785.811	06/29/04	60	44.28	3.90	KV	3.0	37.38	177.0	19.0	0.125	0.55
04-00	280047.104	820978.081	862484.797	232822.692	06/30/04	0	44.28	0.00	KV	3.0	41.28	141.0	17.6	>2.00	0.99
04-08	280049.376	820977.366	862492.251	232820.346	06/30/04	8	44.28	0.60	KV	3.0	40.68	153.0	18.6	0.410	1.83
04-16	280051.823	820976.908	862500.280	232818.843	06/30/04	16	44.28	1.35	KV	3.0	39.93	152.0	16.5	0.120	0.49
04-24	280054.128	820976.421	862507.842	232817.245	06/30/04	24	44.28	1.60	KV	3.0	39.68	155.0	16.9	0.110	0.69
04-32	280056.333	820975.889	862515.076	232815.499	06/30/04	32	44.28	2.05	KV	3.0	39.23	163.0	16.5	0.170	0.98
04-40	280058.733	820975.438	862522.950	232814.020	06/30/04	40	44.28	2.70	KV	3.0	38.58	182.0	16.6	0.105	0.33
04-50	280061.682	820974.856	862532.625	232812.110	06/30/04	50	44.28	3.35	KV	3.0	37.93	177.0	17.4	0.100	0.07
04-60	280064.694	820974.111	862542.507	232809.665	06/30/04	60	44.28	4.00	KV	3.0	37.28	110.0	17.3	0.165	0.39
05-00	280051.524	820984.420	862499.299	232843.489	06/30/04	0	44.28	0.00	KV	3.0	41.28	77.0	19.1	>2.00	0.46
05-08	280054.176	820983.558	862508.000	232840.660	06/30/04	8	44.28	0.55	KV	3.0	40.73	191.0	17.2	0.150	0.34
05-16	280056.472	820982.944	862515.532	232838.646	06/30/04	16	44.28	1.25	KV	3.0	40.03	152.0	18.1	>2.00	1.89
05-24	280059.684	820982.322	862526.070	232836.605	06/30/04	24	44.28	1.70	KV	3.0	39.58	126.0	19.8	>2.00	1.94
05-32	280061.571	820981.932	862532.261	232835.325	06/30/04	32	44.28	2.10	KV	3.0	39.18	157.0	21.2	>2.00	1.37
05-40	280063.788	820981.494	862539.535	232833.888	06/30/04	40	44.28	2.70	KV	3.0	38.58	129.0	22.6	>2.00	1.08
05-50	280066.894	820980.841	862549.725	232831.745	06/30/04	50	44.28	3.35	KV	3.0	37.93	118.0	20.5	0.250	0.28
05-60	280070.206	820980.072	862560.592	232829.222	06/30/04	60	44.28	4.15	KV	3.0	37.13	107.0	19.8	0.330	0.95
06-00	280057.353	820989.964	862518.423	232861.677	06/30/04	0	44.28	0.00	KV	3.0	41.28	66.0	19.8	>2.00	0.10
06-08	280060.001	820989.353	862527.111	232859.672	06/30/04	8	44.28	0.65	KV	3.0	40.63	178.0	20.2	0.335	1.22
06-16	280062.183	820988.928	862534.269	232858.278	06/30/04	16	44.28	1.30	KV	3.0	39.98	144.0	20.8	0.200	1.55

USGS Location ID	NAD83 Easting (m)	NAD83 Northing (m)	NAD27 Easting (ft)	NAD27 Northing (ft)	Date Sampled	Distance from Shore (ft)	Pond Stage (ft above NGVD29)	Water Depth (ft)	Drive-Point Method	Drive Length (ft)	Alt. Bot. of Drive Point (ft above NGVD29)	Specific Conductance (µS/cm)	Temp (^{o}C)	Oxygen, dissolved (mg/L)	Field Phosphorus, dissolved (mg/L as P)
06-24	280064.433	820988.778	862541.651	232857.786	06/30/04	24	44.28	1.70	KV	3.0	39.58	131.0	20.5	0.160	3.20
06-32	280066.849	820988.577	862549.578	232857.126	06/30/04	32	44.28	2.15	KV	3.0	39.13	137.5	20.8	0.340	2.12
06-40	280069.110	820988.292	862556.996	232856.191	06/30/04	40	44.28	2.70	KV	3.0	38.58	160.0	19.0	0.435	1.03
06-50	280072.024	820988.041	862566.556	232855.367	06/30/04	50	44.28	3.40	KV	3.0	37.88	125.9	20.1	0.185	1.17
06-60	280075.231	820987.667	862577.078	232854.140	06/30/04	60	44.28	4.10	KV	3.0	37.18	97.0	20.8	0.350	1.11
07-00	280060.944	820996.721	862530.205	232883.846	06/30/04	0	44.28	0.00	KV	3.0	41.28	65.1	18.1	>2.00	0.10
07-08	280063.775	820996.226	862539.493	232882.221	06/30/04	8	44.28	0.55	KV	3.0	40.73	169.0	18.2	0.700	0.64
07-16	280066.006	820995.773	862546.812	232880.735	06/30/04	16	44.28	1.40	KV	3.0	39.88	156.0	18.6	0.250	1.96
07-24	280068.499	820995.481	862554.992	232879.777	06/30/04	24	44.28	1.75	KV	3.0	39.53	179.0	16.1	>2.00	1.81
07-32	280070.894	820995.084	862562.849	232878.474	06/30/04	32	44.28	2.30	KV	3.0	38.98	134.0	19.1	0.060	1.09
07-40	280073.478	820994.623	862571.327	232876.962	06/30/04	40	44.28	2.80	KV	3.0	38.48	117.0	19.1	0.450	0.16
07-50	280076.957	820994.144	862582.741	232875.390	06/30/04	50	44.28	3.50	KV	3.0	37.78	91.7	16.4	0.155	0.95
07-60	280079.378	820993.809	862590.684	232874.290	06/30/04	60	44.28	4.00	KV	3.0	37.28	89.4	18.0	>2.00	0.62
08-00	280065.793	821000.238	862546.114	232895.384	07/01/04	0	44.28	0.00	KV	3.0	41.28	63.6	17.6	>2.00	0.13
08-08	280067.758	821000.433	862552.561	232896.024	07/01/04	8	44.28	0.60	KV	3.0	40.68	133.7	17.6	>2.00	0.49
08-16	280070.102	821000.406	862560.251	232895.935	07/01/04	16	44.28	1.15	KV	3.0	40.13	172.5	17.5	>2.00	2.48
08-24	280072.491	821000.242	862568.089	232895.397	07/01/04	24	44.28	1.70	KV	3.0	39.58	160.6	19.1	0.720	1.88
08-32	280074.985	820999.943	862576.271	232894.416	07/01/04	32	44.28	2.30	KV	3.0	38.98	124.4	22.1	0.915	1.96
08-40	280077.555	820999.672	862584.703	232893.526	07/01/04	40	44.28	2.90	KV	3.0	38.38	109.0	21.7	>2.00	1.44
08-50	280080.618	820999.446	862594.752	232892.785	07/01/04	50	44.28	3.45	KV	3.0	37.83	82.0	22.1	>2.00	0.65
08-60	280083.631	820998.945	862604.637	232891.141	07/01/04	60	44.28	4.00	KV	3.0	37.28	89.6	23.0	>2.00	0.29
09-00	280069.665	821007.061	862558.817	232917.769	07/01/04	0	44.28	0.00	KV	3.0	41.28	206.0	22.6	>2.00	0.62
09-08	280072.123	821006.803	862566.882	232916.922	07/01/04	8	44.28	0.70	KV	3.0	40.58	134.0	22.8	>2.00	1.29
09-16	280074.496	821006.537	862574.667	232916.049	07/01/04	16	44.28	1.30	KV	3.0	39.98	216.0	17.2	0.125	1.99
09-24	280076.671	821006.498	862581.803	232915.921	07/01/04	24	44.28	1.70	KV	3.0	39.58	191.0	17.6	0.245	1.11
09-32	280079.196	821005.927	862590.087	232914.048	07/01/04	32	44.28	2.35	KV	3.0	38.93	107.0	19.8	0.695	0.83
09-40	280081.581	821005.782	862597.912	232913.572	07/01/04	40	44.28	2.85	KV	3.0	38.43	82.5	18.2	>2.00	0.78
09-50	280084.640	821005.504	862607.948	232912.660	07/01/04	50	44.28	3.60	KV	2.5	38.18	84.0	20.1	>2.00	0.69
09-60	280087.650	821004.985	862617.823	232910.957	07/01/04	60	44.28	4.10	KV	3.0	37.18	85.8	21.1	>2.00	0.46
10-00	280073.027	821013.714	862569.848	232939.596	07/01/04	0	44.28	0.00	KV	3.0	41.28	100.8	19.0	>2.00	0.70
10-08	280075.768	821012.781	862578.840	232936.535	07/01/04	8	44.28	0.65	KV	3.0	40.63	148.0	19.4	0.625	1.94
10-16	280077.933	821012.497	862585.944	232935.603	07/01/04	16	44.28	1.30	KV	3.0	39.98	213.0	19.8	0.095	1.86
10-24	280080.511	821013.915	862594.402	232940.255	07/01/04	24	44.28	1.70	KV	3.0	39.58	121.0	21.4	0.355	1.81
10-32	280082.813	821013.178	862601.954	232937.837	07/01/04	32	44.28	2.20	KV	3.0	39.08	71.8	20.4	>2.00	0.73
10-40	280085.315	821012.682	862610.163	232936.209	07/01/04	40	44.28	2.80	KV	3.0	38.48	77.6	21.7	>2.00	0.90
10-50	280088.266	821012.201	862619.845	232934.631	07/01/04	50	44.28	3.30	KV	3.0	37.98	73.6	23.1	>2.00	0.21
10-60	280091.531	821011.980	862630.557	232933.906	07/01/04	60	44.28	4.05	KV	3.0	37.23	90.7	21.5	>2.00	0.42
11-00	280077.346	821019.074	862584.018	232957.181	07/01/04	0	44.28	0.00	KV	3.0	41.28	80.0	18.1	>2.00	0.18
11-08	280079.559	821019.182	862591.278	232957.535	07/01/04	8	44.28	0.55	KV	3.0	40.73	153.0	21.7	>2.00	0.24
11-16	280081.355	821020.151	862597.171	232960.714	07/01/04	16	44.28	1.35	KV	3.0	39.93	133.9	17.9	>2.00	0.83
11-24	280083.854	821020.350	862605.370	232961.367	07/01/04	24	44.28	1.60	KV	3.0	39.68	68.5	18.7	>2.00	0.91
11-32	280086.141	821020.581	862612.873	232962.125	07/01/04	32	44.28	2.10	KV	3.0	39.18	75.5	18.5	>2.00	0.98
11-40	280088.669	821020.580	862621.167	232962.121	07/01/04	40	44.28	2.70	KV	3.0	38.58	76.2	20.5	>2.00	0.52
11-50	280092.000	821020.271	862632.095	232961.107	07/01/04	50	44.28	3.25	KV	3.0	38.03	92.2	20.8	>2.00	0.39
11-60	280094.944	821020.689	862641.754	232962.479	07/01/04	60	44.28	3.85	KV	3.0	37.43	88.6	20.1	>2.00	0.08
12-00	280080.257	821025.370	862593.569	232977.837	07/01/04	0	44.28	0.00	KV	3.0	41.28	108.1	18.3	>2.00	0.16
12-08	280082.231	821025.524	862600.045	232978.342	07/01/04	8	44.28	0.60	KV	3.0	40.68	158.7	15.7	2.150	0.98
12-16	280084.287	821025.748	862606.790	232979.077	07/01/04	16	44.28	1.30	KV	3.0	39.98	99.2	16.3	>2.00	0.07
12-24	280086.690	821026.042	862614.674	232980.042	07/01/04	24	44.28	1.75	KV	3.0	39.53	75.9	18.3	>2.00	0.46
12-32	280089.095	821025.951	862622.565	232979.743	07/01/04	32	44.28	2.20	KV	3.0	39.08	72.7	16.0	>2.00	0.55

USGS Location ID	NAD83 Easting (m)	NAD83 Northing (m)	NAD27 Easting (ft)	NAD27 Northing (ft)	Date Sampled	Distance from Shore (ft)	Pond Stage (ft above NGVD29)	Water Depth (ft)	Drive-Point Method	Drive Length (ft)	Alt. Bot. of Drive Point (ft above NGVD29)	Specific Conductance (µS/cm)	Temp (^oC)	Oxygen, dissolved (mg/L)	Field Phosphorus, dissolved (mg/L as P)
12-40	280091.458	821026.491	862630.317	232981.514	07/01/04	40	44.28	2.75	KV	3.0	38.53	88.2	16.5	>2.00	0.29
12-50	280094.446	821026.791	862640.121	232982.498	07/01/04	50	44.28	3.25	KV	3.0	38.03	88.0	16.6	>2.00	0.08
12-60	280097.495	821026.944	862650.124	232983.000	07/01/04	60	44.28	4.00	KV	3.0	37.28	91.7	17.6	>2.00	0.03
13-00	280081.339	821031.397	862597.119	232997.611	07/02/04	0	44.28	0.00	KV	3.0	41.28	100.5	16.5	>2.00	0.16
13-08	280083.654	821030.939	862604.714	232996.108	07/02/04	8	44.28	0.80	KV	3.0	40.48	164.3	15.1	2.360	0.69
13-16	280086.752	821030.675	862614.878	232995.242	07/02/04	16	44.28	1.40	KV	3.0	39.88	74.8	15.6	>2.00	0.57
13-24	280089.362	821030.591	862623.441	232994.966	07/02/04	24	44.28	1.90	KV	3.0	39.38	70.6	18.6	>2.00	0.49
13-32	280091.554	821030.576	862630.632	232994.917	07/02/04	32	44.28	2.45	KV	3.0	38.83	88.3	19.0	>2.00	0.13
13-40	280094.246	821030.538	862639.465	232994.792	07/02/04	40	44.28	3.00	KV	3.0	38.28	87.6	17.0	>2.00	0.20
13-50	280097.388	821030.374	862649.773	232994.253	07/02/04	50	44.28	3.65	KV	3.0	37.63	88.8	17.2	>2.00	0.07
13-60	280100.631	821030.259	862660.413	232993.876	07/02/04	60	44.28	4.40	KV	2.5	37.38	91.7	20.2	>2.00	0.11
14-00	280087.172	821037.429	862616.256	233017.400	07/02/04	0	44.28	0.00	KV	3.5	40.78	91.3	17.3	>2.00	0.23
14-08	280087.424	821037.973	862617.083	233019.185	07/02/04	8	44.28	0.70	KV	3.0	40.58	176.0	15.0	>2.00	0.44
14-16	280089.741	821037.960	862624.684	233019.142	07/02/04	16	44.28	1.50	KV	3.0	39.78	67.5	16.7	>2.00	0.41
14-24	280092.312	821038.020	862633.120	233019.339	07/02/04	24	44.28	1.80	KV	3.0	39.48	68.8	18.5	>2.00	0.36
14-32	280094.880	821037.534	862641.545	233017.744	07/02/04	32	44.28	2.50	KV	3.0	38.78	87.4	17.7	>2.00	0.20
14-40	280096.884	821037.377	862648.120	233017.229	07/02/04	40	44.28	2.95	KV	3.0	38.33	91.7	17.1	>2.00	0.15
14-50	280100.009	821037.551	862658.372	233017.800	07/02/04	50	44.28	3.70	KV	3.0	37.58	91.4	18.1	>2.00	0.07
14-60	280103.066	821037.306	862668.402	233016.996	07/02/04	60	44.28	4.45	KV	3.0	36.83	93.4	18.7	>2.00	0.11
15-00	280089.266	821043.640	862623.126	233037.778	07/02/04	0	44.28	0.00	KV	3.0	41.28	86.0	18.6	>2.00	0.08
15-08	280090.941	821044.189	862628.622	233039.579	07/02/04	8	44.28	0.75	KV	3.0	40.53	185.0	16.9	>2.00	0.23
15-16	280093.083	821043.388	862635.649	233036.951	07/02/04	16	44.28	1.45	KV	3.0	39.83	77.6	17.8	>2.00	0.16
15-24	280095.251	821043.585	862642.762	233037.597	07/02/04	24	44.28	2.00	KV	3.0	39.28	66.7	16.9	>2.00	0.05
15-32	280097.468	821045.393	862650.036	233043.528	07/02/04	32	44.28	2.50	KV	3.0	38.78	93.2	19.2	>2.00	0.20
15-40	280099.973	821044.466	862658.254	233040.487	07/02/04	40	44.28	3.05	KV	3.0	38.23	80.0	17.5	>2.00	0.08
15-50	280103.425	821044.267	862669.580	233039.834	07/02/04	50	44.28	3.90	KV	3.0	37.38	99.5	18.8	>2.00	0.05
15-60	280106.350	821044.122	862679.176	233039.358	07/02/04	60	44.28	4.15	KV	3.0	37.13	92.8	18.9	>2.00	

Table 2. Field and laboratory chemical analysis of samples collected from pre-barrier temporary pond-bottom multilevel drive points.

[F shorthand for MA-FSW. Length of sampling interval is 0.04 ft. Elevations of all permanently installed devices were determined on October 6, 2004 by the U.S. Geological Survey. Altitude is in feet relative to NGVD29. pH values were determined and nitrogen samples were collected at three of the 10 profiles. mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25°C; ---, no analysis; <, actual value less than method detection limit. Dissolved oxygen and field phosphorus were determined onsite using a colorimetric photometer. Source of nitrogen and phosphorus (non-field) data: U.S. Geological Survey National Water Quality Lab, Denver, CO]

Local Site Identifier	Easting NAD83 (meters)	Northing NAD83 (meters)	Date Sampled	Depth Below Pond Bottom (feet)	Altitude of midpoint of screen (feet)	Specific Conductance (µS/cm)	Oxygen, dissolved (mg/L)	Field phosphorus, dissolved (mg/L as P)	pH (standard units)	Nitrogen, ammonium, dissolved (mg/L as N)	Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)
F639P01-0000	280020.694	820958.223	7/20/04	0.02	42.84	95	8.3	0.07	6.9	<0.04	<0.06	<0.008	<0.01
F639P01-0000.8	280020.694	820958.223	7/20/04	0.82	42.04	120	2.1	0.13	6	<0.04	2.45	<0.008	<0.01
F639P01-0001.6	280020.694	820958.223	7/20/04	1.6	41.26	138	---	0.05	5.9	----	----	----	<0.01
F639P01-0002.2	280020.694	820958.223	7/20/04	2.2	40.66	153	---	0.57	---	----	----	----	<0.01
F639P01-0003.4	280020.694	820958.223	7/20/04	3.4	39.46	98	0.7	0.15	---	<0.04	3.22	<0.008	0.05
F640P01-0000	280041.839	820972.412	7/21/04	0.02	43.22	98	8.4	0.20	7.2	----	----	----	0.20
F640P01-0000.8	280041.839	820972.412	7/21/04	0.82	42.42	153	0.7	1.35	6.5	0.04	0.14	0.005	1.67
F640P01-0001.6	280041.839	820972.412	7/21/04	1.6	41.64	162	0.9	1.58	6.5	---	---	---	1.20
F640P01-0002.2	280041.839	820972.412	7/21/04	2.2	41.04	160	0.7	1.35	6.6	---	---	---	1.15
F640P01-0003.4	280041.839	820972.412	7/21/04	3.4	39.84	129	7.6	1.26	6.6	0.41	<0.06	<0.008	1.06
F641P01-0000	280053.525	820975.195	7/21/04	0.02	41.59	97	8.4	0.20	7.3	---	---	---	0.06
F641P01-0000.8	280053.525	820975.195	7/21/04	0.82	40.79	160	2.1	0.96	6.7	0.79	<0.06	<0.008	1.20
F641P01-0001.6	280053.525	820975.195	7/21/04	1.6	40.01	162	0.5	1.39	6.9	---	---	---	1.04
F641P01-0002.2	280053.525	820975.195	7/21/04	2.2	39.41	161	0.5	1.21	6.6	---	---	---	1.00
F641P01-0003.4	280053.525	820975.195	7/21/04	3.4	38.21	159	0.1	0.34	6.9	0.86	<0.06	<0.008	1.12
F642P01-0000	280053.247	820983.820	7/21/04	0.02	43.60	101	8.4	0.44	7.2	<0.04	<0.06	<0.008	0.33
F642P01-0000.8	280053.247	820983.820	7/21/04	0.82	42.80	148	0.7	1.70	6.6	0.04	<0.06	<0.008	1.46
F642P01-0001.6	280053.247	820983.820	7/21/04	1.6	42.02	154	0.4	1.81	6.7	0.04	<0.06	<0.008	1.45
F642P01-0002.2	280053.247	820983.820	7/21/04	2.2	41.42	142	0.7	1.16	6.6	0.04	<0.06	<0.008	1.45
F642P01-0003.4	280053.247	820983.820	7/21/04	3.4	40.22	149	---	1.39	6.7	0.04	<0.06	<0.008	1.38
F643P01-0000	280063.169	820997.399	7/22/04	0.02	43.82	103	7.8	0.28	6.4	---	---	---	0.14
F643P01-0000.8	280063.169	820997.399	7/22/04	0.82	43.02	64	7.3	0.39	6	<0.04	<0.06	<0.008	0.26
F643P01-0001.6	280063.169	820997.399	7/22/04	1.6	42.24	70	8.2	0.44	6.4	---	---	---	0.28
F643P01-0002.2	280063.169	820997.399	7/22/04	2.2	41.64	196	7.8	0.57	6.3	---	---	---	0.52
F643P01-0003.4	280063.169	820997.399	7/22/04	3.4	40.44	244	8.1	1.57	6.4	<0.04	0.33	<0.008	1.05
F644P01-0000	280069.031	820992.213	7/22/04	0.02	42.30	121	5.5	0.78	7	---	---	---	0.49
F644P01-0000.8	280069.031	820992.213	7/22/04	0.82	41.50	153	0.7	1.16	6.5	1.25	<0.06	<0.008	1.71
F644P01-0001.6	280069.031	820992.213	7/22/04	1.6	40.72	154	2.2	1.47	6.8	---	---	---	1.70
F644P01-0002.2	280069.031	820992.213	7/22/04	2.2	40.12	150	0.1	1.60	6.8	---	---	---	1.61
F644P01-0003.4	280069.031	820992.213	7/22/04	3.4	38.92	148	4.9	2.15	6.7	1.23	<0.06	<0.008	1.71
F645P01-0000	280078.725	820993.792	7/22/04	0.02	40.68	92	8.3	0.86	7.2	<0.04	0.68	<0.008	0.59
F645P01-0000.8	280078.725	820993.792	7/22/04	0.82	39.88	89	4.6	0.80	6.7	<0.04	0.81	<0.008	0.69
F645P01-0001.6	280078.725	820993.792	7/22/04	1.6	39.10	90	1.9	0.80	6.5	<0.04	0.82	<0.008	0.70
F645P01-0002.2	280078.725	820993.792	7/22/04	2.2	38.50	88	7.3	0.80	6.6	<0.04	0.83	<0.008	0.63
F645P01-0003.4	280078.725	820993.792	7/22/04	3.4	37.30	92	7.6	0.54	7	<0.04	0.17	<0.008	0.15
F646P01-0000	280072.638	821009.799	7/22/04	0.02	43.52	121	5.8	1.22	6.4	---	---	---	0.77
F646P01-0000.8	280072.638	821009.799	7/22/04	0.82	42.72	151	0.6	1.66	6.2	0.03	<0.06	<0.008	1.37
F646P01-0001.6	280072.638	821009.799	7/22/04	1.6	41.94	150	1.4	1.76	6.3	---	---	---	1.40
F646P01-0002.2	280072.638	821009.799	7/22/04	2.2	41.34	147	---	0.64	6.4	---	---	---	1.05
F646P01-0003.4	280072.638	821009.799	7/22/04	3.4	40.14	116	0.2	0.82	6.2	0.43	<0.06	<0.008	1.45
F647P01-0000	280082.332	821017.239	7/23/04	0.02	42.48	72	6.5	0.46	5.5	<0.04	0.47	<0.008	0.73
F647P01-0000.8	280082.332	821017.239	7/23/04	0.82	41.68	70	6.2	1.14	6.4	<0.04	0.48	<0.008	0.72
F647P01-0001.6	280082.332	821017.239	7/23/04	1.6	40.90	70	6.2	0.95	6.6	<0.04	0.47	<0.008	0.71
F647P01-0002.2	280082.332	821017.239	7/23/04	2.2	40.30	70	6	0.90	6.2	<0.04	0.47	<0.008	0.71
F647P01-0003.4	280082.332	821017.239	7/23/04	3.4	39.10	70	6	0.95	6.5	<0.04	0.47	<0.008	0.73
F648P01-0000	280083.009	821027.609	7/23/04	0.02	43.30	95	6.8	0.88	6.2	---	---	---	0.51
F648P01-0000.8	280083.009	821027.609	7/23/04	0.82	42.50	100	4.4	0.86	6	<0.04	0.45	<0.008	0.70
F648P01-0001.6	280083.009	821027.609	7/23/04	1.6	41.72	104	2.7	1.06	6.1	---	---	---	0.83
F648P01-0002.2	280083.009	821027.609	7/23/04	2.2	41.12	102	2.1	1.04	6.2	---	---	---	0.92
F648P01-0003.4	280083.009	821027.609	7/23/04	3.4	39.92	101	2.3	0.95	6.2	<0.04	0.35	<0.008	0.94

APPENDIX C

Field Implementation Photo Log

Picture 1

Shoreline of Ashumet Pond prior to barrier construction. (8/10/2004)

Picture 2

Initiation of construction of HDPE grid mat system, Fisherman's Cove. (8/10/2004)

Picture 3

Construction of HDPE grid mat system with containment boom offshore. (8/11/2004)

Picture 4

Positioning of bladder cofferdam. 8/12/2004)

Picture 5

Pump placement with portable secondary containment and boom/silt curtain off shore. (8/12/2004)

Picture 6

Initial bladder cofferdam filling on north side of construction zone. (8/17/2004)

Picture 7

Bladder cofferdam placement initial filling on south end of construction zone. (8/17/2004)

Picture 8

Super sacks of ZVI staged in Boat Ramp parking area. (8/17/2004)

Picture 9

Mobilization of second portable pump to barrier construction area. (8/17/2004)

Picture 10

Completion of filling of bladder cofferdam structure. (8/18/2004)

Picture 11

Initial dewatering underway within cofferdam. (8/18/2004)

Picture 12

Unloading of high-capacity (6 in.) pump to aid dewatering of construction area. (8/19/2004)

Picture 13

Relocation of large pump to barrier construction area. (8/19/2004)

Picture 14

Allu screening bucket. (8/24/2004)

Picture 15

Initiation of excavation work, north end of barrier area. Dewatering underway. (8/24/2004)

Picture 16

Dewatering underway with three pumps operating. (8/24/2004)

Picture 17

Dewatering stabilized with three pumps operating. (8/24/2004)

Picture 18

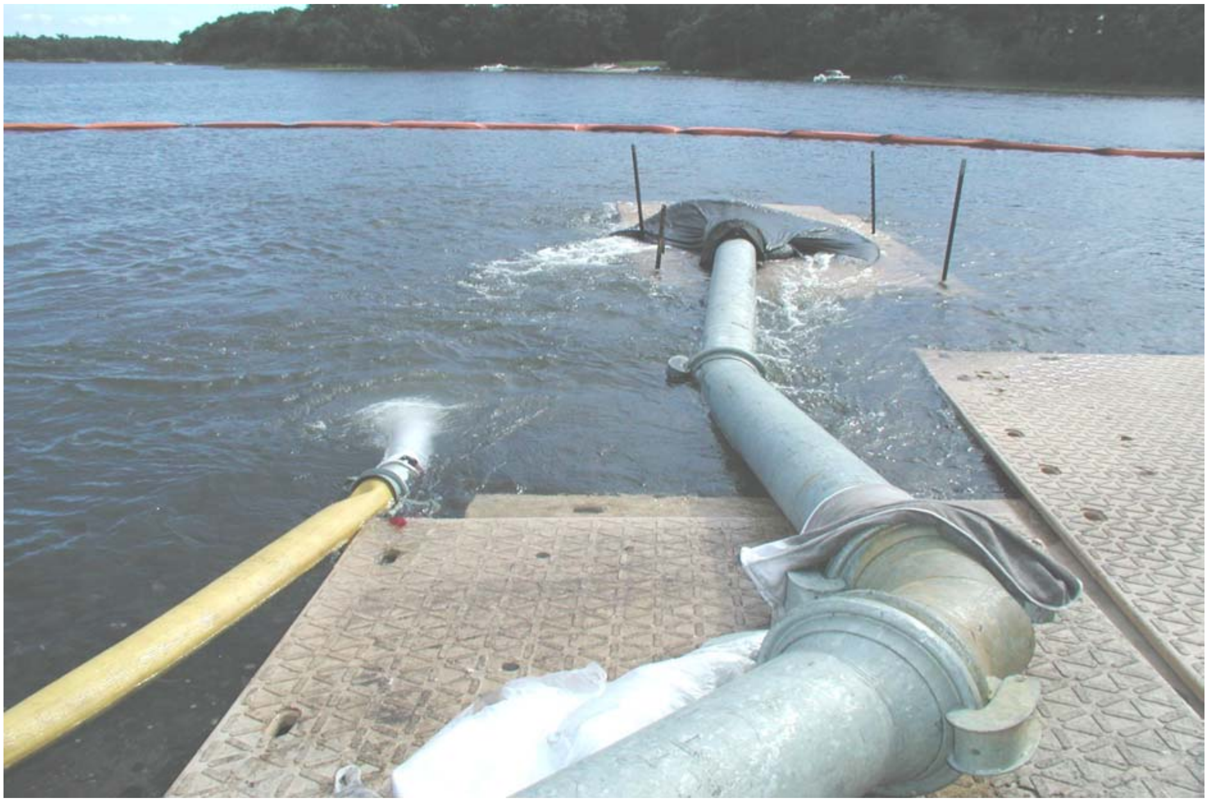
Initial excavation and sediment screening. (8/24/2004)

Picture 19

Sediment screening. (8/24/2004)

Picture 20

Archeologist from Public Archeology Lab (PAL) inspecting excavated sediments. (8/24/2004)



Picture 21

Pump discharge area. Note filter bags on discharge lines, flow attenuation structure for large pump, and boom/silt curtain containing the area. (8/24/2004)

Picture 22

ZVI placement and mixing in excavated sediments. (8/25/2004)

Picture 23

ZVI mixing in excavated sediments. (8/25/2004)

Picture 24

View to the north across barrier construction area. (8/25/2004)

Picture 25

Excavation awaiting backfilling. Note pond water in-fill. (8/25/2004)

Picture 26

USGS locating horizontal multilevel sampler in excavation to be backfilled. (8/26/2004)

Picture 27

Pond side view of excavation/mixing activities within bladder cofferdam. (8/27/2004)

Picture 28

USGS construction of secure vaults on shore for horizontal multilevel sampling devices. (8/28/2004)

Picture 29

Pond side view of excavation/mixing activities within bladder cofferdam. (8/26/2004)

Picture 30

USGS placement of southern multilevel sampling device. (8/26/2004)

Picture 31

USGS placement of southern multilevel sampling device. (8/26/2004)

Picture 32

PAL archeologist observing excavation/mixing process. (8/30/2004)

Picture 33

USGS seepage meters installed. Bottom surface to be smoothed. (8/30/2004)

Picture 34

Excavation/mixing of sediments at south end of barrier area. (8/30/2004)

Picture 35

Sediment excavation/mixing complete and demobilization underway. (8/31/2004)

Picture 36

Bladder cofferdam pumping (deflation) underway. (8/31/2004)

Picture 37

Bladder cofferdam removal. (9/03/2004)

Picture 38

Final draining of bladder cofferdam section. (9/07/2004)

Picture 39

Geochemical barrier area under restored pond stage. (9/07/2004)

Picture 40

Shoreline of Ashumet Pond following barrier construction. (9/16/2004)

APPENDIX D

Barrier Construction Quality Assurance

(Data Available Upon Request)

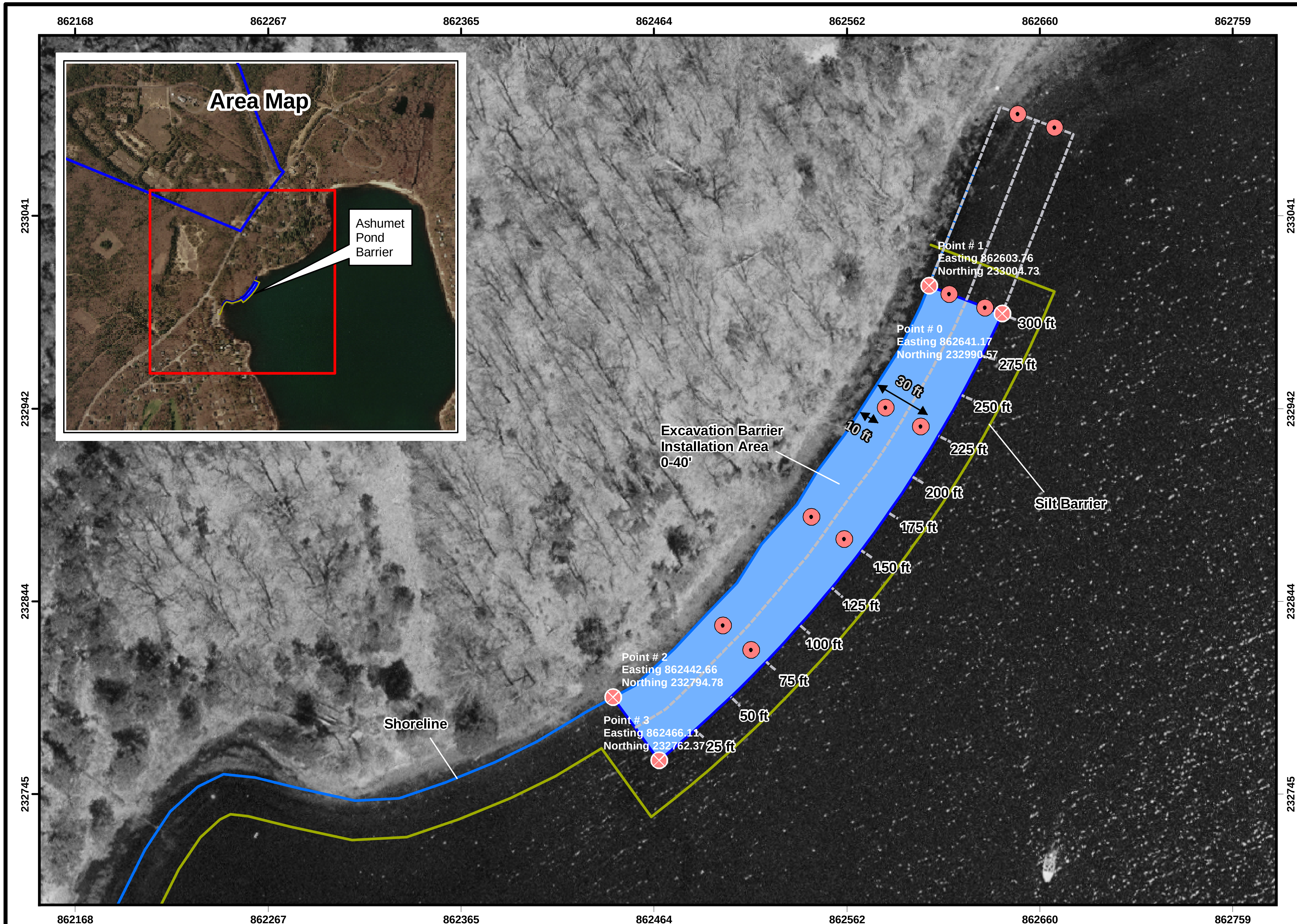
ENVIRONMENTAL
CHEMICAL CORPORATION

<table>
<tr><td>Client, Project and Location
AFCEE, Ashumet Pond Geochemical Barrier at the Massachusetts Military Reservation, Cape Cod</td><td colspan="2">**Project Note 01**</td><td>Task Order No.
0025
ECC Project No.
4030.025</td></tr>
<tr><td colspan="2">Confirmation of:
☒ Technical/Project Work Plan
☐ Client Meeting Notes
☐ Quality Control Meeting</td><td colspan="2">~~Date Held: not applicable~~
~~Location: not applicable~~
Date Issued: June 14, 2004
Prepared by: Kimberly Johnson</td></tr>
<tr><td colspan="2">Subject: **Site Preparation Plan**</td><td colspan="2">Issued By: Kimberly Johnson
Environmental Chemical Corporation</td></tr>
<tr><td colspan="4">~~Participants or~~ Copies To: Jon Davis, AFCEE; John Blount, CH2MHill; BG Chabot, ECC; John Feeley, ECC; ECC File</td></tr>
</table>

Item	Remarks
1	**<u>Introduction</u>** Environmental Chemical Corporation (ECC) has been tasked under Contract No. F41624-01-D-8551 Task Order 025 to install a geochemical barrier at Ashumet Pond, which is located adjacent to the Massachusetts Military Reservation (MMR), Cape Cod, MA. This Sampling Plan has been prepared to describe the means and methods that will be used to perform the Pre-Installation Sampling event and activities associated with the sampling event. For information on the Geochemical Barrier Installation please refer to the *Draft Ashumet Pond Geochemical Barrier for Phosphorus Removal Design Testing & Installation Workplan* (CH2MHill, May 2004).
2	**<u>Pre-Installation Sediment Sampling</u>** ECC will follow the AFCEE approved QPP (CH2MHill 2002) and the ECC HSP that was prepared specifically for the Multiple Source Remediation Program at MMR. Below please find a detailed summary of sampling plan and activities that are required to complete the Pre-Installation Sampling at Ashumet Pond. Prior to the installation of the Geochemical Barrier ECC will collect sediment samples from ten (10) locations just north of and within the barrier area as outlined in Figure 1 (Attachment 1). Sediment samples will be collected from the top foot of the pond sediment according to related sections and procedures (Tech Procedure 022 Attached) found in the MMR Quality Program Plan (AFCEE, 2002). The sample locations will be measured 10 and 30 feet from the shoreline at 100 feet north of the Barrier Area and then at the centerline of each of the four 75 X 40 foot grids within the barrier (Figure 1). Samples will be collected from a boat using a ponar dredge method. As described in Section 7.2 of the *Draft Ashumet Pond Geochemical Barrier for Phosphorus Removal Design Testing & Installation Workplan* (CH2MHill, May 2004), samples will be screened using a 40 mesh sieve and all particles coarser than 40 mesh will be discarded. The material finer than 40 mesh will be homogenized and a representative sample will be sent off-site for analyses of Iron, Manganese, and Phosphorus. Analyses for Iron and Manganese will be via Method SW-846 and for Phosphorus via 365-3. Sample jars, labels, chain-of-custody and analyses will be performed by ESS laboratory.
3	**<u>Quality Control & Safety Plan</u>** A. A Quality Program Plan (QPP) was developed by AFCEE for the Comprehensive Plume Response Plan at MMR (Jacobs, 2000). This QPP was adopted by ECC for managing the Multiple Source

	Remediation Project at MMR. The QPP provides a complete description of the quality assurance (QA) measures required to complete remedial action program activities. There are two main components to the QPP, as described below: 1. The Construction Quality Plan (CQP) is intended to ensure that completed activities meet or exceed all design criteria, plans, and specifications and that all contract quality objectives are met. The CQP addresses construction operations both on-site and off-site, including work done by subcontractors, fabricators, suppliers, and purchasing agents. All subcontractor personnel are required to adhere to the CQP. The CQP has a three-phase inspection system, at various stages of work activity. Inspections are conducted for the preparatory, initial and completion stages of each definable feature of work. Copies of inspection reports are available in the project files. 2. The QAPP is applicable to all work conducted at MMR on behalf of AFCEE. It outlines the program's QC objectives and describes a comprehensive set of sampling, analysis, QA and QC, data validation and assessment guidelines. B. ECC will conduct all sampling activities in compliance with the approved Health and Safety Plan (HSP), which was prepared by ECC specifically for the Multiple Source Remediation Program at MMR.
4	<u>**Concurrence**</u> Concurrence with above Sampling Plan is represented by the signatures below. ____________________________ AFCEE Project Manager/COR ____________________________ ECC QC/Geologist ____________________________ ECC Project Manager

Attachment 1



Contract No.	F41624-01-D-8551
Description	Ashumet Pond Sample Locations
Coordinate System	NAD 1927, MA State Plane in feet
Sources	MMR boundary, roads and 2002 aerial digital orthophotos provided by MA ARNG.

		Rev.	Date	Approved
Date	10-JUN-2004			
Drawn	J. Kim			
Checked	K. Johnson			
Approved				

Legend

- Stake-out points of Barrier
- Sampling Points
- Silt Barrier
- Shoreline (2003)
- Barrier
- MMR boundary

0 25 50 100 Feet

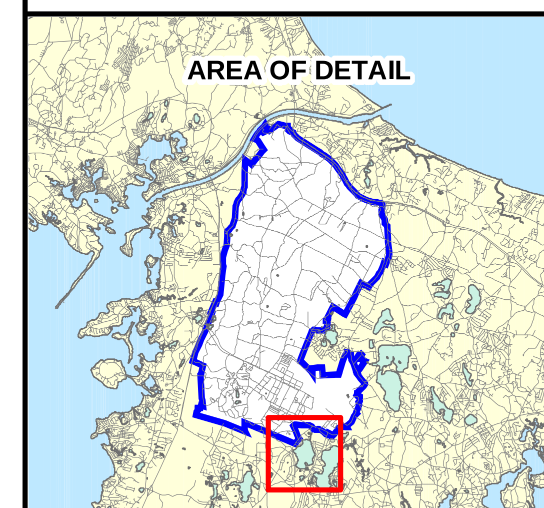


Figure 1

Title:

Ashumet Pond Pre-Installation Sample Locations

Environmental Chemical Corporation
318B E. Inner Rd.
OTIS ANGB, MA 02542

Attachment 2

SEDIMENT SAMPLING

1.0 PURPOSE

The purpose of this technical procedure is to outline protocols for sampling sediments. This procedure applies to the collection of sediment samples in surface water bodies from areas of deposition, such as streams, rivers, ditches, lakes, ponds, and lagoons.

2.0 SCOPE

This procedure applies to all Jacobs personnel and subcontractors collecting sediment samples.

3.0 REFERENCES

1. U.S. Environmental Protection Agency (EPA). 1987. *A Compendium of Superfund Field Operations Methods.* EPA/540/P-87/001.

4.0 DEFINITIONS

N/A.

5.0 GENERAL

When both surface water and sediment samples are to be collected, the surface water sample will be collected first (according to MMR TECH 017), as disturbing the sediment may influence the analytical results of the surface water samples and cause cross contamination.

If sampling both surface water and sediment, or just sediment, sample from the most downstream point first and proceed upstream.

When collecting sediment samples to be analyzed for volatile organic compounds (VOCs), do not pool or homogenize the sample. Slowly decant off any liquid phase and then fill the specified container(s) with the solid, ensuring no head space. Samples for nonvolatile organic and inorganic analyses can be placed in an appropriate collection pan or bowl and homogenized before they are placed in sample containers.

If the person collecting the sediment sample needs to enter the water in order to collect the sample, this should be done downstream of the actual sample location and care must be taken not to disturb the sediment in the location to be sampled.

Wear appropriate personal protective equipment (PPE) as prescribed by the Health and Safety Plan (HSP).

If sampling from a boat or near water bodies with a depth of five feet or more, additional health and safety requirements are required.

6.0 RESPONSIBILITIES

6.1 Project Manager

The *Project Manager* is responsible for ensuring overall compliance with this technical procedure.

6.2 Sample Manager

The *Sample Manager* is responsible for assigning qualified personnel and having required equipment available to sample sediment.

6.3 Field Sampling Personnel

Field Sampling Personnel are responsible for collecting sediment samples in accordance with this technical procedure and any modifications included in the site-specific plan.

7.0 PROCEDURE

The water content of the sediment may vary greatly. Likewise, the sediments themselves may range from very soft to dense. It may be necessary to use a variety of equipment to obtain the required samples, even at a single site.

7.1 Equipment

- stainless steel, polytetrafluoroethelyne (PTFE), or PTFE-lined sampling tray or bowl
- stainless steel or PTFE dip sampler, scoops, trowels, spoons, ladles
- PVC pipe, 2 inch diameter
- sand core sediment sampler, liners (optional) and extensions
- jaw type sampler
- sample bottles
- sample cooler with ice
- rubber boots/waders
- plastic sheeting
- utility knife
- rope
- boat (optional)
- PPE (as required in the HSP)
- field notebook with waterproof markers
- decontamination equipment, as appropriate
- plastic bucket (for rinse water/solvents, decant and or spoils)
- appropriate sample data forms (e.g., COCs)

- clear tape
- pen, pencil, Magic Marker, etc.
- sample labels
- paper towels
- garbage bag for PPE

7.2 Sampling Procedures

- On arrival at the site, set up and organize sampling equipment near the first (farthest downstream) sample location.
- Cut a section of plastic sheet to be placed on the ground to use as a clean staging area for sampling equipment.
- Arrange sample containers, sampling equipment, and decontaminated equipment on the plastic sheet. Exercise caution not to step on, or otherwise contaminate this clean working surface
- Don PPE in accordance with the site HSP.
- Collect surface water sample, if required.
- Collect sediment sample. The preferred methods of collecting sediment samples will be by hand corer or PVC pipe.
- For all samples, mark the sampling location on a site map. Photograph (optional but recommended) and describe each location, and place a numbered stake above the visible high water mark on the bank closest to the sampling location. The photographs and description must be adequate to allow the sampling station to be relocated at a future date.

7.2.1 Hand Corer Method

- Label each sample container properly, cover label with clear tape, fill out appropriate chain of custody information, wipe outside of container with paper towel or Kim wipe, and place in iced cooler.
- Ensure that the corers and (optional) liners are properly decontaminated prior to initiation of sampling and between each sample location.
- Gently push the corer into the sediment with a smooth continuous motion to a depth of approximately 9 inches.
- Twist the corer to detach the sample; then withdraw the corer in a single smooth motion.
- Remove top of corer and slowly decant excess water.
- Remove the nosepiece and deposit the sample onto a stainless steel, PTFE, or PTFE-lined tray or bowl.
- Decant, if appropriate and necessary.
- Transfer the sample into sample containers (VOCs first) using a stainless steel laboratory spoon (or equivalent device). The transfer equipment may be disposable to avoid decontamination costs, and the risk of cross-contamination. If specific data quality objectives mandate (except for VOC samples), the sample shall be

homogenized in a bowl using sampling spoon prior to placement into sample containers.

- Decontaminate equipment for the next sample location or at the conclusion of all sampling.

7.2.2 PVC Pipe Method (for very soft sediments only)

- Label each sample container properly, cover label with clear tape, fill out appropriate chain of custody information, wipe outside of container with paper towel or Kim wipe, and place in iced cooler.
- Gently push pipe into sediment with a smooth continuous motion to a depth of approximately 9 inches.
- Cap the pipe, forming an airtight seal, to create a vacuum as it is withdrawn from the sediment.
- Slowly decant excess water.
- Deposit the sample onto a stainless steel or PTFE tray or bowl.
- Decant if appropriate and necessary.
- Transfer the sample into sample containers (VOCs first) using a stainless steel laboratory spoon (or equivalent device). The transfer equipment may be disposable to avoid decontamination costs, and the risk of cross-contamination. If specific data quality objectives mandate (except for VOC samples), the sample shall be homogenized in a bowl using sampling spoon prior to placement into sample containers.
- Decontaminate equipment.

7.2.3 Ponar Dredge Method (for deep water sampling from a boat)

- A Ponar dredge can be used to collect sediment samples from deep water impoundments or flowing streams. This type of sampler has a jaw-type mechanism that is tripped from above in order to close the jaws and collect the sample. The dredge is lowered slowly through the water to the sediment with the jaws in the open position. As the dredge is retrieved, the jaws close and the isolated sediment is brought to the surface.
- Pre-weighed VOA, VOC Sediment Sampling:

  1.Obtain the sediment sample using the the Ponar as described above.
  2.Using the supplied syringes, quickly remove approximately 5-10 mls of sediment from the Ponar and transfer it to the provided pre-weighed 40 ml vial.
  3.Repeat step 2 to fill the second vial.
  4.Fill the 2 ounce jar for percent solids.
  5. Record the volume used for each sample in your logbook as well as on the chain-of-custody (COC).
  Note:Do not apply tape on pre-weighed VOA vials, but on the outside of the bag.

- Decant if appropriate and necessary.

- Deposit the Ponar contents onto a stainless steel or PTFE (Teflon) tray or bowl.
- Transfer the sample into sample containers using a stainless steel laboratory spoon (or equivalent device). The transfer equipment may be disposable to avoid decontamination costs, and the risk of cross-contamination. If specific data quality objectives mandate (except for VOC samples), the sample shall be homogenized in a bowl using sampling spoon prior to placement into sample containers.
- Label each sample container properly, cover label with clear tape, fill out appropriate chain of custody information, wipe outside of container with paper towel or Kim wipe, and place in iced cooler.
- Decontaminate equipment.

7.2.4 Scoop, Trowel, Spoon, or Ladle, Sampling Method

- Label each sample container properly, cover label with clear tape, fill out appropriate chain of custody information, wipe outside of container with paper towel or Kim wipe, and place in iced cooler.
- Insert the sampling device into the sediment at the selected sampling point and slowly remove the sample.
- Slowly decant excess water.
- Deposit the sample into a stainless steel or PTFE tray or bowl.
- Transfer the sample into sample containers (VOCs first) using a stainless steel laboratory spoon (or equivalent device). The transfer equipment may be disposable to avoid decontamination costs, and the risk of cross-contamination. If specific data quality objectives mandate (except for VOC samples), the sample shall be homogenized in a bowl using sampling spoon prior to placement into sample containers.
- Decontaminate equipment prior to collecting sample from next location.

7.3 Investigative-Derived Material (IDM)

Dispose of all sampling waste and PPE in properly labeled containers in accordance with the IDM Management Plan.

7.4 Decontamination

All sampling equipment shall be decontaminated before each use and between each location in accordance with technical procedure MMR TECH-036, Equipment Decontamination Procedures.

8.0 RECORDS

All field notes shall be documented in accordance with technical procedure MMR TECH-035, Field Logbook.

Reviewed by: ____
Quality Assurance Manager

Approved by: ____
Program Manager, Plume Response Program

APPENDIX E

Post-Installation Groundwater Analytical Data

Appendix E

Ashumet Pond Geochemical Barrier for Phosphorus Removal
Post-Installation Field Monitoring Results (USGS)

List of Figures

List of tables

Table 4, Appendix E
Ashumet Pond Geochemical Barrier
TEMPORARY DRIVE POINT SAMPLING
(POST-INSTALLATION)
2 - 5 November 2004

Location	Sampling Location	Sampling Date	Sample Depth (Below Pond Bottom)	Total Phosphorus as P (mg/L)	Dissolved Phosphorus as P (mg/L)	pH (pH UNITS)	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (US/CM)
95DP301025A	Background	11/2/2004	1	0.5100 J	0.596	6.6	12.6	0.51	175
95DP301025A	Background	11/2/2004	3	0.7300 J	0.796	6.83	12	0.5	167
95DP301025B	Barrier	11/2/2004	1	ND	ND	7.08	12.4	0.02	205
95DP301025B	Barrier	11/2/2004	3	1.7500 J	1.742	6.37	11.8	0.36	203
95DP302075A	Background	11/2/2004	1	0.8200 J	0.845	6.68	11.8	0.13	160
95DP302075A	Background	11/2/2004	3	1.0000 J	1.001	6.89	11.7	0.46	153
95DP302075B	Barrier	11/2/2004	0.5	0.0205 J	0.0084	7.12	12.3	2.82	142
95DP302075B	Barrier	11/2/2004	1	0.0023 J	ND	7.33	11.8	0.06	222
95DP302075B	Barrier	11/2/2004	2	0.169	0.171	6.75	11.7	0.13	188
95DP302075B	Barrier	11/2/2004	3	1.76	1.768	6.51	11.6	7.55	140
95DP303150A*	Barrier Edge	11/2/2004	1	0.294	0.335	7.08	11	0.33	157
95DP303150A*	Barrier Edge	11/2/2004	3	1.1500 J	0.68	6.85	11	0.83	142
95DP303150B	Barrier	11/4/2004	0.5	0.0043	0.0036	6.6	11	0.12	288
95DP303150B	Barrier	11/4/2004	1	0.0035	0.0098	7.03	11	0	262
95DP303150B	Barrier	11/4/2004	2	0.204	0.246	6.9	11	0.61	221
95DP303150B	Barrier	11/4/2004	3	1.323	1.451	6.42	10.9	0.04	243
95DP304225A	Barrier	11/4/2004	1	0.0428	0.0352	6.85	11.3	0.09	170
95DP304225A	Barrier	11/4/2004	3	0.825	0.746	6.36	10.9	3.07	147
95DP304225B	Barrier	11/4/2004	1	0.0335	0.0212	6.7	11	0.18	200
95DP304225B	Barrier	11/4/2004	3	1.695	NS	6.84	11.1	0.66	188
95DP305275A	Barrier	11/4/2004	1	0.0254	0.0094	7.03	11.1	0.46	90
95DP305275A	Barrier	11/4/2004	3	1.084	0.399	6.68	11	7.03	68
95DP305275B	Background	11/4/2004	1	1.13	0.628	6.05	10.9	4.44	190
95DP305275B	Background	11/4/2004	2	1.111	0.618	6.08	10.9	2.36	191
95DP305275B	Background	11/4/2004	3	0.924	0.609	6.03	11	5.1	186

* = Anomalous data due to location on edge of barrier
NS = Not Sampled

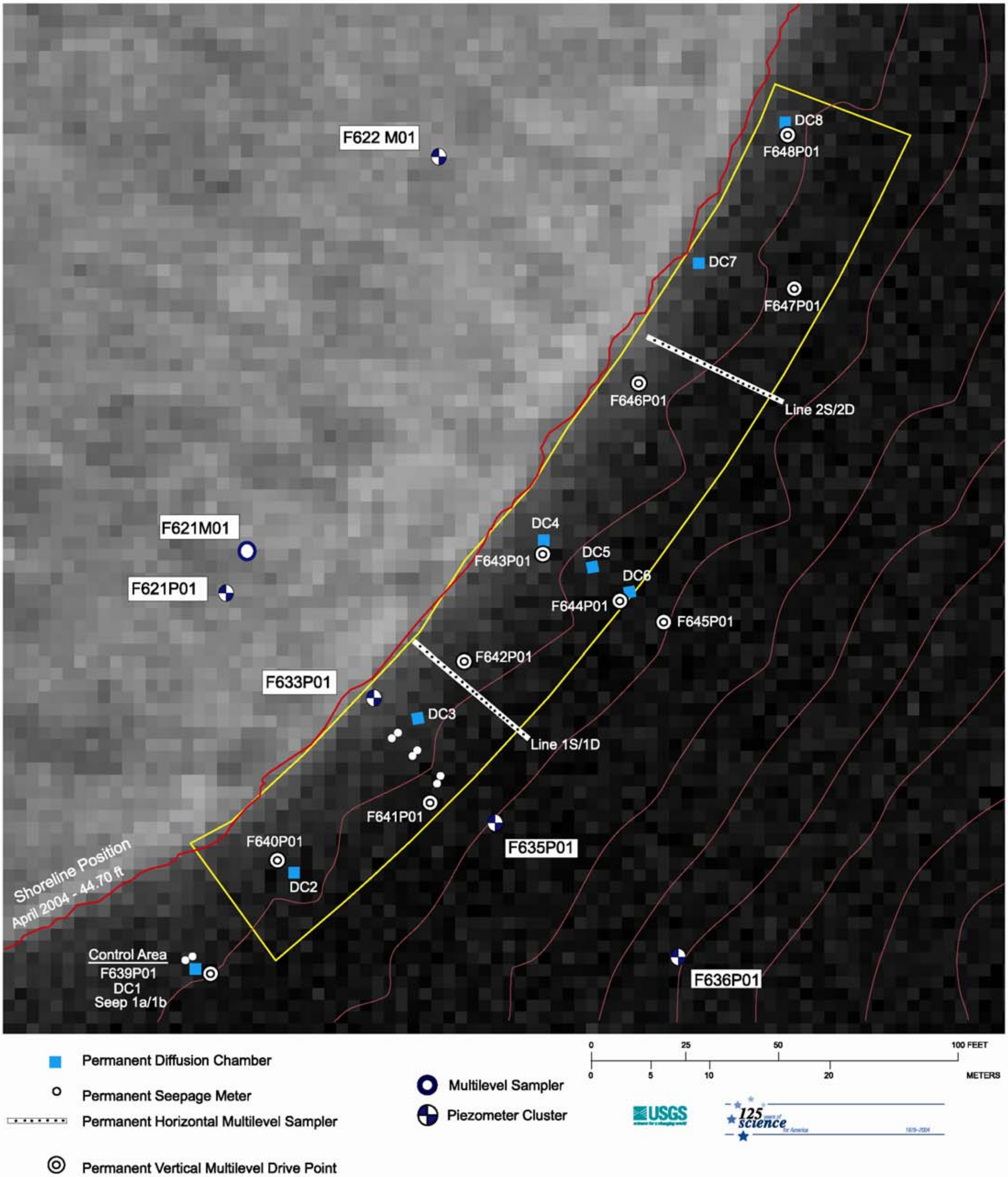


Figure Final locations of permanent seepage meters, multilevel drive points, horizontal multilevel samplers, and diffusion chambers in geochemical barrier area of Ashumet Pond. (Total seepage locations = 4, total multilevel drive points = 8, total MLS lines = 2 (coupled), total diffusion chamber locations = 8).

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APPENDIX E (FIGURE 1)
Barrier Performance Monitoring Network Location Map

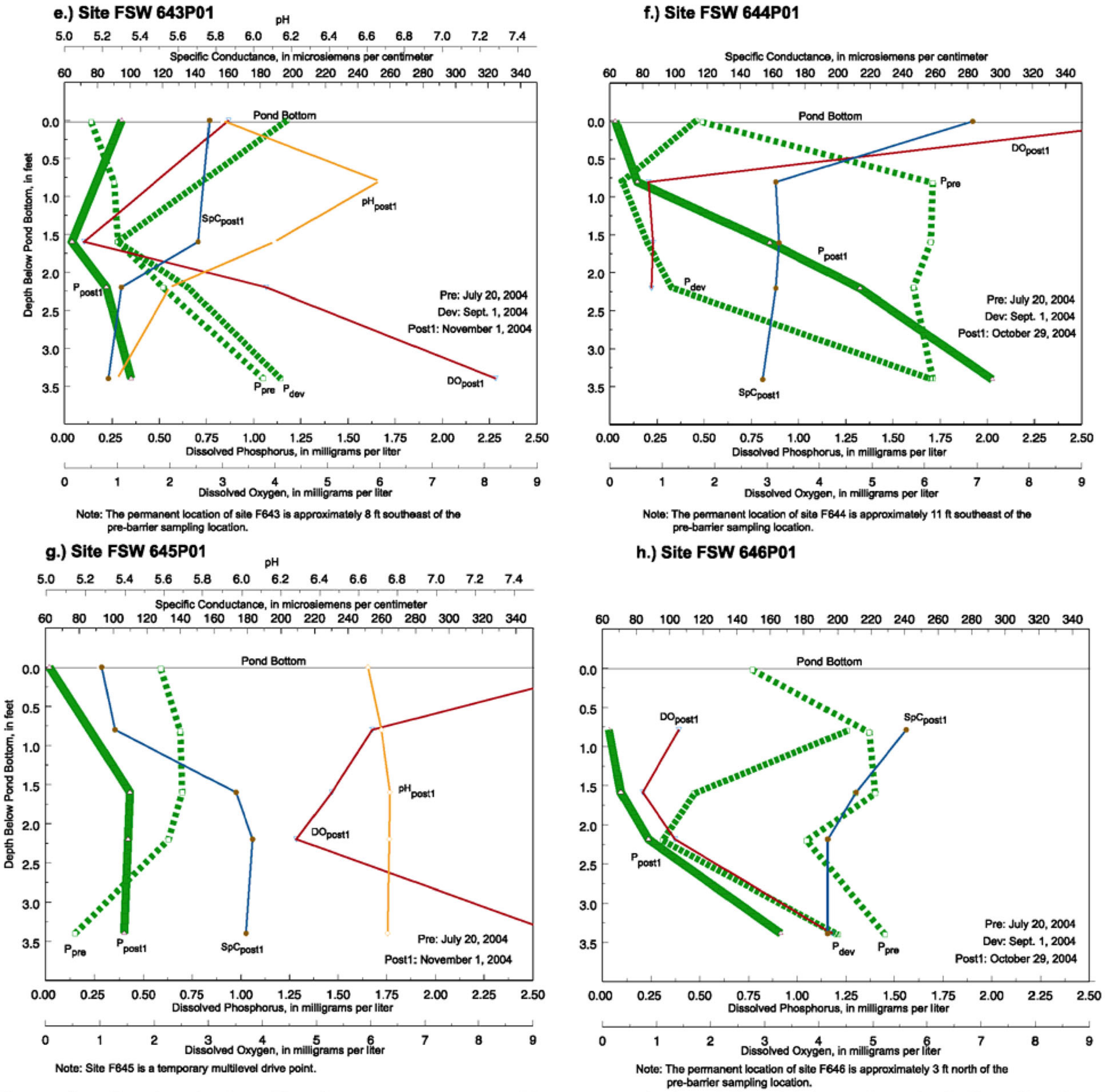
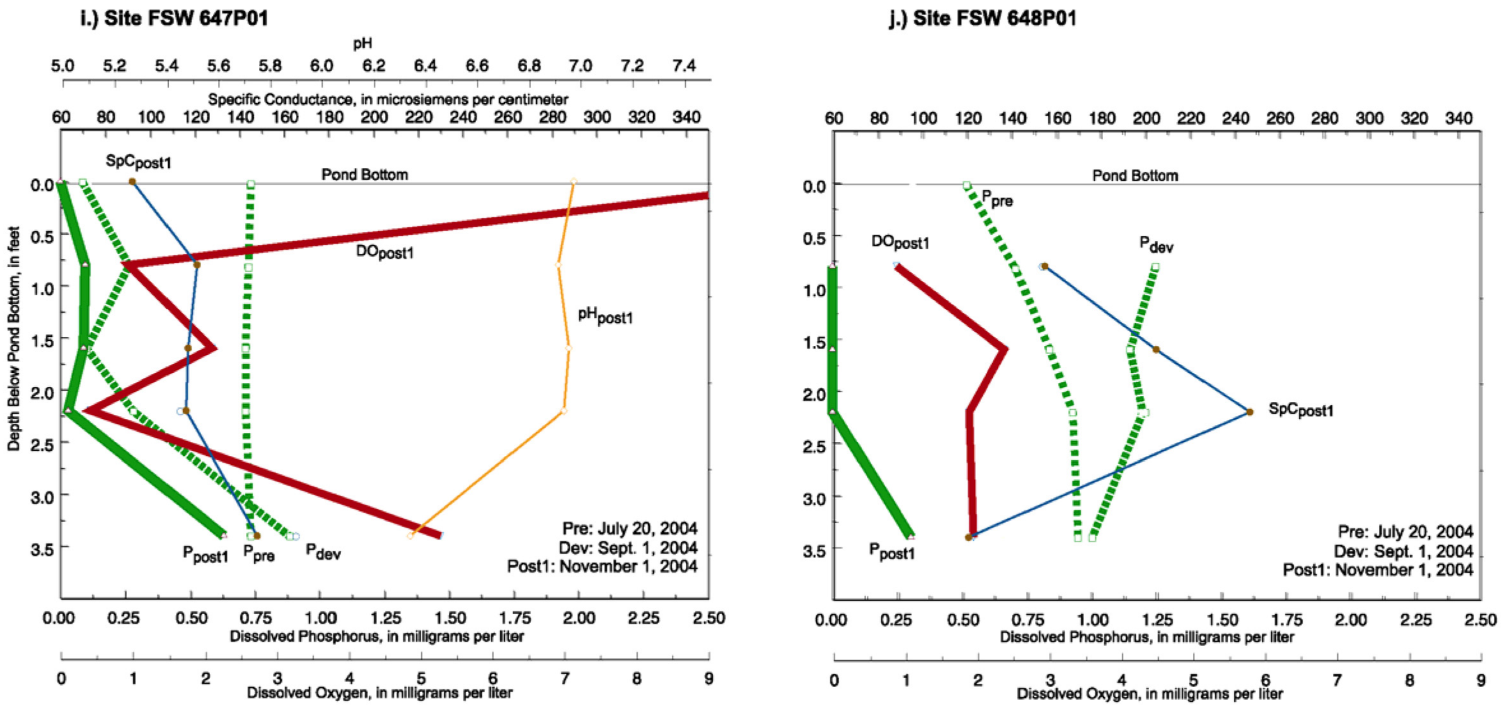


Figure 2a Geochemical profiles from permanent pond-bottom vertical multilevel drive points, including dissolved phosphorus levels prior to installation of the geochemical barrier, during instrumentation development one week after barrier installation, and two months after installation.



Note: The permanent location of site F647 is approximately 4 ft west of the pre-barrier sampling location.

Note: The permanent location of site F648 is approximately 3 ft southwest of the pre-barrier sampling location.

Figure 2b. Geochemical profiles from permanent pond-bottom vertical multilevel drive points, including dissolved phosphorus levels prior to installation of the geochemical barrier, during instrumentation development one week after barrier installation, and two months after installation.

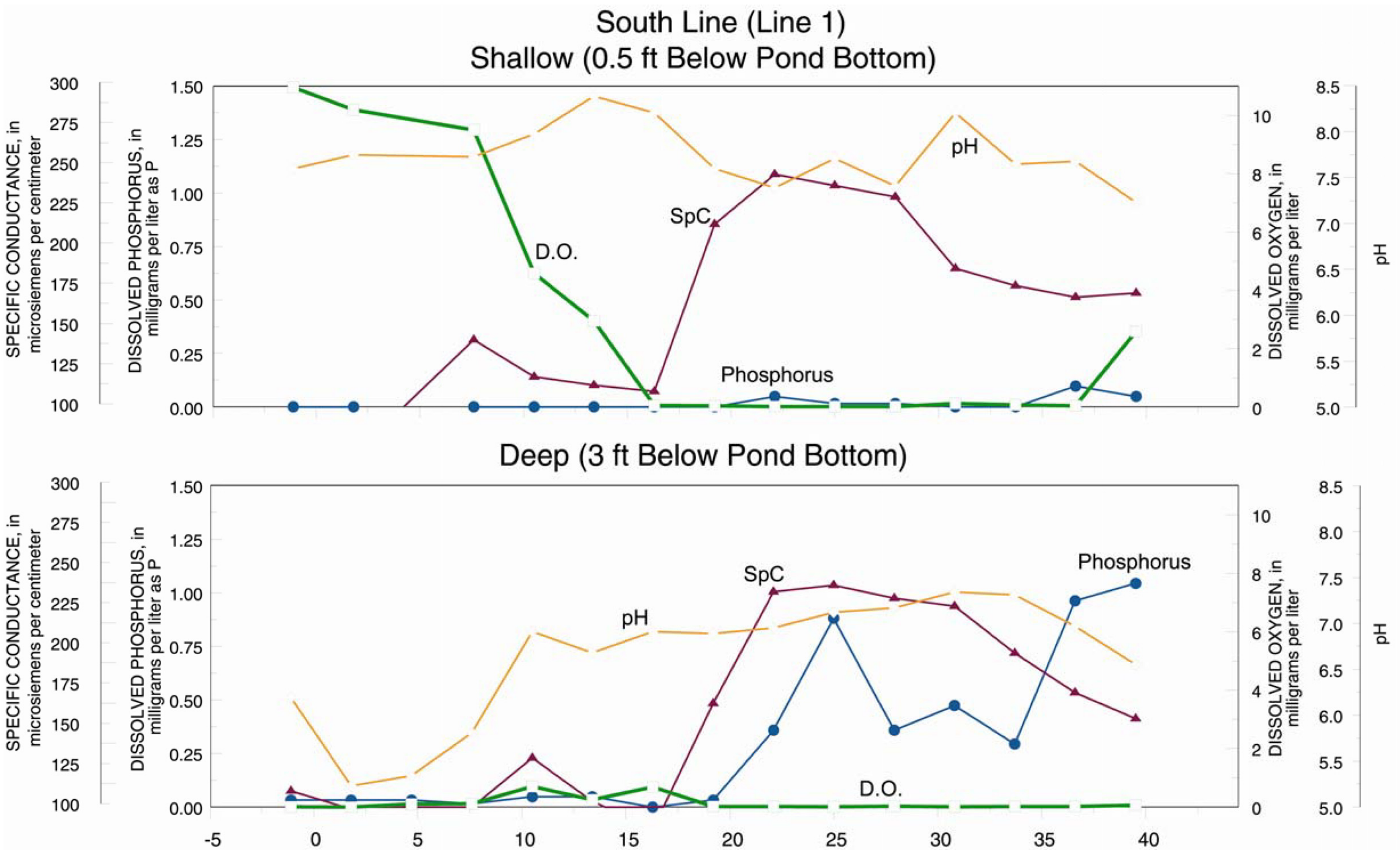


Figure 3a. Field parameters and dissolved phosphorus concentrations in two horizontal multilevel samplers installed at 0.5 and 3.0 feet below the pond bottom along one of two transects in the geochemical barrier.

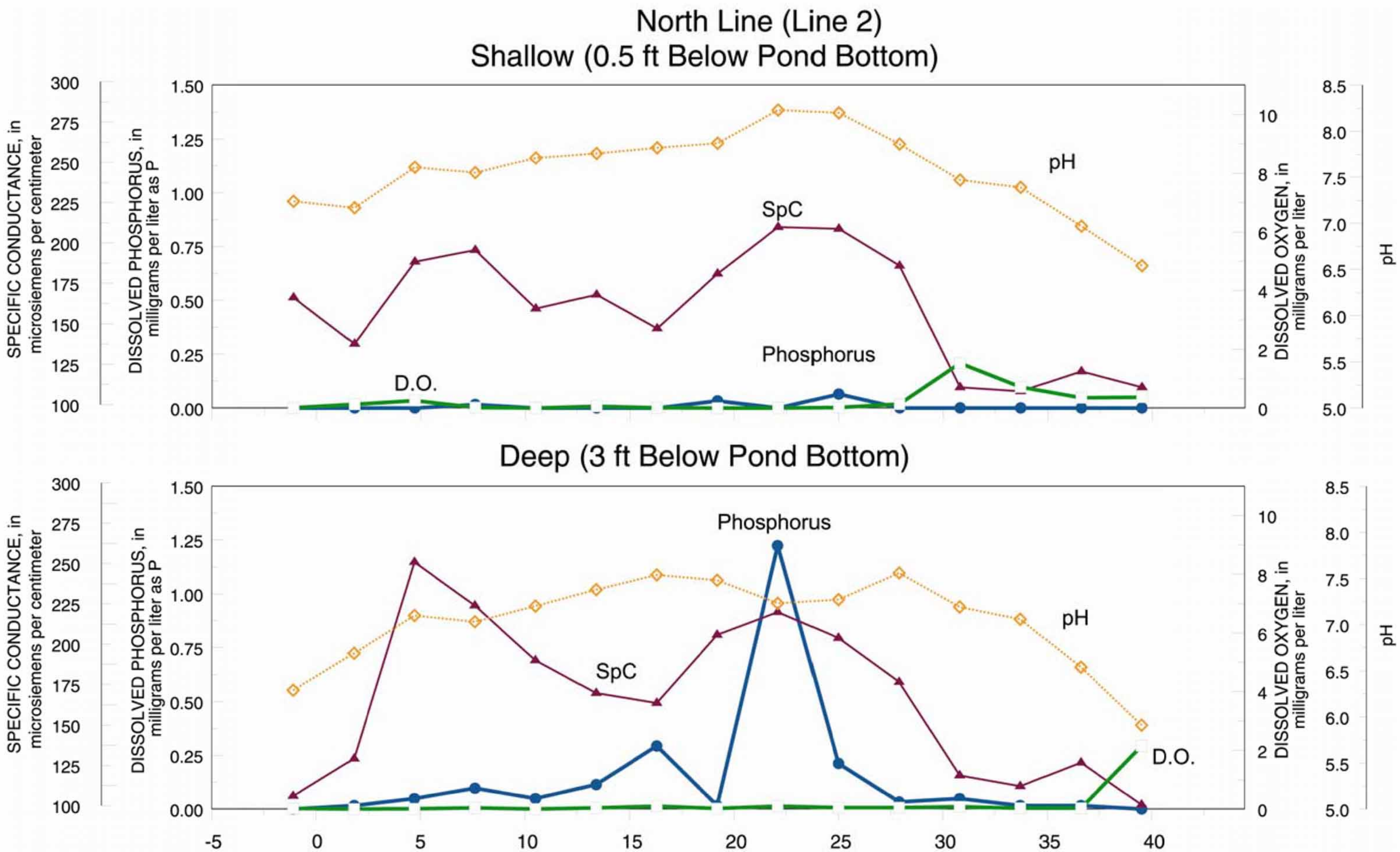


Figure 3b. Field parameters and dissolved phosphorus concentrations in two horizontal multilevel samplers installed at 0.5 and 3.0 feet below the pond bottom along one of two transects in the geochemical barrier.

Appendix E

Table 1. Location data and field chemical analysis for samples collected during development of permanent pond-bottom multilevel drive points, one week after installation.

[F shorthand for MA-FSW. Length of sampling interval is 0.04 ft. Elevations of all permanently installed devices were determined on October 6, 2004 by the U.S. Geological Survey. Altitude is in feet relative to NGVD29. mg/L, milligrams per liter;µS/cm, microsiemens per centimeter at 25oC;-----, no analysis, Dissolved oxygen and field phosphorus were determined onsite using a colorimetric photometer]

Local Site Identifier	Easting NAD83 (meters)	Northing NAD83 (meters)	Date Sampled	Depth below pond bottom (feet)	Altitude of midpoint of screen (feet)	Specific conductance (µS/cm)	Field phosphorus, dissolved (mg/L as P)	Development Notes
F639P01-0000	280035.999	820958.504	9/1/04	0.02	42.84	222	0.95	
F639P01-0000.8	280035.999	820958.504	9/1/04	0.82	42.04	219	0.65	
F639P01-0001.6	280035.999	820958.504	9/1/04	1.62	41.24	212	0.72	
F639P01-0002.2	280035.999	820958.504	9/1/04	2.22	40.64	208	0.60	
F639P01-0003.4	280035.999	820958.504	9/1/04	3.42	39.44	117	1.71	
F640P01-0000	280041.672	820968.084	9/1/04	0.02	43.22	236	0.36	
F640P01-0000.8	280041.672	820968.084	9/1/04	0.82	42.42	284	0.26	
F640P01-0001.6	280041.672	820968.084	9/1/04	1.62	41.62	227	1.48	
F640P01-0002.2	280041.672	820968.084	9/1/04	2.22	41.02	218	0.86	
F640P01-0003.4	280041.672	820968.084	9/1/04	3.42	39.82	203	1.58	
F641P01-0000	280054.484	820973.004	9/1/04	0.02	41.59	194	0.82	poor yield
F641P01-0000.8	280054.484	820973.004	9/1/04	0.82	40.79	313	0.21	
F641P01-0001.6	280054.484	820973.004	9/1/04	1.62	39.99	268	0.13	
F641P01-0002.2	280054.484	820973.004	9/1/04	2.22	39.39	218	0.21	
F641P01-0003.4	280054.484	820973.004	9/1/04	3.42	38.19	101	0.08	
F642P01-0000	280057.364	820984.858	9/1/04	0.02	43.60	100	1.40	
F642P01-0000.8	280057.364	820984.858	9/1/04	0.82	42.80	124	0.44	
F642P01-0001.6	280057.364	820984.858	9/1/04	1.62	42.00	152	0.29	
F642P01-0002.2	280057.364	820984.858	9/1/04	2.22	41.40	202	0.78	
F642P01-0003.4	280057.364	820984.858	9/1/04	3.42	40.20	---	---	did not pump
F643P01-0000	280064.002	820994.228	9/1/04	0.02	43.82	223	1.17	poor yield
F643P01-0000.8	280064.002	820994.228	9/1/04	0.82	43.02	---	---	did not pump
F643P01-0001.6	280064.002	820994.228	9/1/04	1.62	42.22	206	0.28	
F643P01-0002.2	280064.002	820994.228	9/1/04	2.22	41.62	158	0.65	
F643P01-0003.4	280064.002	820994.228	9/1/04	3.42	40.42	284	1.14	
F644P01-0000	280070.882	820989.998	9/1/04	0.02	42.66	152	0.46	
F644P01-0000.8	280070.882	820989.998	9/1/04	0.82	41.86	240	0.07	
F644P01-0001.6	280070.882	820989.998	9/1/04	1.62	41.06	199	0.20	
F644P01-0002.2	280070.882	820989.998	9/1/04	2.22	40.46	197	0.33	
F644P01-0003.4	280070.882	820989.998	9/1/04	3.42	39.26	198	1.70	
F646P01-0000	280072.137	821008.498	9/1/04	0.02	43.52	---	---	dry due to low pond level
F646P01-0000.8	280072.137	821008.498	9/1/04	0.82	42.72	276	1.26	
F646P01-0001.6	280072.137	821008.498	9/1/04	1.62	41.92	242	0.47	
F646P01-0002.2	280072.137	821008.498	9/1/04	2.22	41.32	227	0.31	
F646P01-0003.4	280072.137	821008.498	9/1/04	3.42	40.12	237	1.21	
F647P01-0000	280085.138	821016.427	9/1/04	0.02	42.48	108	0.08	
F647P01-0000.8	280085.138	821016.427	9/1/04	0.82	41.68	96.0	0.26	
F647P01-0001.6	280085.138	821016.427	9/1/04	1.62	40.88	98.2	0.10	
F647P01-0002.2	280085.138	821016.427	9/1/04	2.22	40.28	113	0.28	
F647P01-0003.4	280085.138	821016.427	9/1/04	3.42	39.08	165	0.88	
F648P01-0000	280084.569	821029.386	9/1/04	0.02	43.30	---	---	dry due to low pond level
F648P01-0000.8	280084.569	821029.386	9/1/04	0.82	42.50	153	1.24	
F648P01-0001.6	280084.569	821029.386	9/1/04	1.62	41.70	152	1.14	
F648P01-0002.2	280084.569	821029.386	9/1/04	2.22	41.10	162	1.19	
F648P01-0003.4	280084.569	821029.386	9/1/04	3.42	39.90	134	0.99	

Appendidx E

Table 2. Field and laboratory chemical analysis of samples collected from permanent pond-bottom multilevel profilers collected two months after barrier installation.

[F shorthand for MA-FSW. Length of sampling interval is 0.04 ft. F645P01 could not be installed during iron-barrier emplacement because of coffer dam, so a temporary drive point was used for the sampling round.Elevations of all permanently installed devices were determined on October 6, 2004 by the U.S. Geological Survey. Altitude is in feet relative to NGVD29. pH values were determined and nitrogen samples were collected at three of the 10 profiles. Dissolved oxygen and field phosphorus were determined onsite using a colorimetric photometer. Source of nitrogen and phosphorus (non-field) data: U.S. Geological Survey National Water Quality Lab, Denver, CO. mg/L, milligrams per liter;µS/cm, microsiemens per centimeter at 25oC; ---, no analysis; <, actual value less than method detection limit]

Local Site Identifier	Easting NAD83 (meters)	Northing NAD83 (meters)	Date Sampled	Depth Below Pond Bottom (feet)	Altitude of midpoint of screen (feet)	Specific Conductance (µS/cm)	Oxygen, dissolved (mg/L)	Field phosphorus, dissolved (mg/L as P)	pH (standard units)	Nitrogen, ammonium, dissolved (mg/L as N)	Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)
F639P01-0000	280035.999	820958.504	10/29/04	0.02	42.84	216	6.83	0.59	---	---	---	---	0.80
F639P01-0000.8	280035.999	820958.504	10/29/04	0.82	42.04	221	2.86	0.57	---	---	---	---	0.73
F639P01-0001.6	280035.999	820958.504	10/29/04	1.62	41.24	227	2.44	0.49	---	---	---	---	0.74
F639P01-0002.2	280035.999	820958.504	10/29/04	2.22	40.64	233	1.32	0.54	---	---	---	---	0.65
F639P01-0003.4	280035.999	820958.504	10/29/04	3.42	39.44	101	10.21	0.03	---	---	---	---	0.03
F640P01-0000	280041.672	820968.084	10/29/04	0.02	43.22	107	2.82	0.11	---	---	---	---	0.02
F640P01-0000.8	280041.672	820968.084	10/29/04	0.82	42.42	119	0.17	0.10	---	---	---	---	0.08
F640P01-0001.6	280041.672	820968.084	10/29/04	1.62	41.62	126	0.75	0.05	---	---	---	---	0.07
F640P01-0002.2	280041.672	820968.084	10/29/04	2.22	41.02	128	3.77	0.75	---	---	---	---	0.96
F640P01-0003.4	280041.672	820968.084	10/29/04	3.42	39.82	156	1.93	0.98	---	---	---	---	1.42
F641P01-0000	280054.484	820973.004	10/29/04	0.02	41.59	144	0.53	0.99	---	---	---	---	1.21
F641P01-0000.8	280054.484	820973.004	10/29/04	0.82	40.79	162	0.58	0.99	---	---	---	---	1.23
F641P01-0001.6	280054.484	820973.004	10/29/04	1.62	39.99	167	0.66	0.86	---	---	---	---	1.03
F641P01-0002.2	280054.484	820973.004	10/29/04	2.22	39.39	165	0.65	0.62	---	---	---	---	0.36
F641P01-0003.4	280054.484	820973.004	10/29/04	3.42	38.19	97.0	---	0.00	---	---	---	---	<0.02
F642P01-0000	280057.364	820984.858	10/29/04	0.02	43.60	---	---	---	---	---	---	---	---
F642P01-0000.8	280057.364	820984.858	10/29/04	0.82	42.80	135	0.39	0.18	---	---	---	---	0.04
F642P01-0001.6	280057.364	820984.858	10/29/04	1.62	42.00	160	2.63	0.16	---	---	---	---	<0.02
F642P01-0002.2	280057.364	820984.858	10/29/04	2.22	41.40	140	0.26	0.60	---	---	---	---	<0.02
F642P01-0003.4	280057.364	820984.858	10/29/04	3.42	40.20	---	---	---	---	---	---	---	---
F643P01-0000	280064.002	820994.228	11/1/04	0.02	43.82	149	3.12	0.28	6.90	0.05	<0.06	<0.008	<0.02
F643P01-0000.8	280064.002	820994.228	11/1/04	0.82	43.02	---	---	---	---	---	---	---	---
F643P01-0001.6	280064.002	820994.228	11/1/04	1.62	42.22	142	0.38	0.15	6.95	<0.04	<0.06	<0.008	0.04
F643P01-0002.2	280064.002	820994.228	11/1/04	2.22	41.62	94.7	3.84	0.07	5.81	<0.04	<0.06	<0.008	0.22
F643P01-0003.4	280064.002	820994.228	11/1/04	3.42	40.42	86.7	8.22	0.28	5.79	<0.04	<0.06	<0.008	0.35
F644P01-0000	280070.882	820989.998	10/29/04	0.02	42.66	283	10.51	0.07	---	---	---	---	0.03
F644P01-0000.8	280070.882	820989.998	10/29/04	0.82	41.86	162	0.74	0.21	---	---	---	---	0.15
F644P01-0001.6	280070.882	820989.998	10/29/04	1.62	41.06	164	0.82	0.62	---	---	---	---	0.85
F644P01-0002.2	280070.882	820989.998	10/29/04	2.22	40.46	162	0.79	0.98	---	---	---	---	1.33
F644P01-0003.4	280070.882	820989.998	10/29/04	3.42	39.26	154	---	1.61	---	---	---	---	2.03
F645P01-0000	280078.725	820993.792	11/1/04	0.02	40.68	93.2	10.53	0.03	5.95	<0.04	0.051	<0.008	0.02
F645P01-0000.8	280078.725	820993.792	11/1/04	0.82	39.88	101	6.03	0.08	6.20	<0.04	0.795	<0.008	0.36
F645P01-0001.6	280078.725	820993.792	11/1/04	1.62	39.08	173	5.28	0.29	6.36	<0.04	0.845	<0.008	0.43
F645P01-0002.2	280078.725	820993.792	11/1/04	2.22	38.48	183	4.63	0.00	6.35	<0.04	<0.06	<0.008	0.42
F645P01-0003.4	280078.725	820993.792	11/1/04	3.42	37.28	179	9.45	0.10	6.32	<0.04	0.692	<0.008	0.40
F646P01-0000	280072.137	821008.498	10/29/04	0.02	43.52	---	---	---	---	---	---	---	---
F646P01-0000.8	280072.137	821008.498	10/29/04	0.82	42.72	242	1.44	0.51	---	---	---	---	0.04
F646P01-0001.6	280072.137	821008.498	10/29/04	1.62	41.92	212	0.77	0.26	---	---	---	---	0.10
F646P01-0002.2	280072.137	821008.498	10/29/04	2.22	41.32	195	1.37	0.23	---	---	---	---	0.24
F646P01-0003.4	280072.137	821008.498	10/29/04	3.42	40.12	195	4.27	0.69	---	---	---	---	0.92
F647P01-0000	280085.138	821016.427	11/1/04	0.02	42.48	92.2	10.60	0.02	7.14	<0.04	<0.06	<0.008	<0.02
F647P01-0000.8	280085.138	821016.427	11/1/04	0.82	41.68	121	0.95	0.24	6.92	<0.04	<0.06	<0.008	0.10
F647P01-0001.6	280085.138	821016.427	11/1/04	1.62	40.88	117	2.10	0.10	7.07	<0.04	<0.06	<0.008	0.09
F647P01-0002.2	280085.138	821016.427	11/1/04	2.22	40.28	116	0.42	0.00	7.00	<0.04	0.044	<0.008	0.03
F647P01-0003.4	280085.138	821016.427	11/1/04	3.42	39.08	148	5.28	0.52	4.86	<0.04	0.303	<0.008	0.63
F648P01-0000	280084.569	821029.386	10/29/04	0.02	43.30	---	---	---	---	---	---	---	---
F648P01-0000.8	280084.569	821029.386	10/29/04	0.82	42.50	155	0.89	0.46	---	---	---	---	<0.02
F648P01-0001.6	280084.569	821029.386	10/29/04	1.62	41.70	205	2.39	0.51	---	---	---	---	<0.02
F648P01-0002.2	280084.569	821029.386	10/29/04	2.22	41.10	247	1.90	0.46	---	---	---	---	<0.02
F648P01-0003.4	280084.569	821029.386	10/29/04	3.42	39.90	121	1.96	0.47	---	---	---	---	0.30

Appendix E

Table 3. Location data and field chemical analysis of samples collected from four horizontal multilevel samplers installed at 0.5 and 3.0 feet below the pond bottom along two transects in the geochemical barrier.

[Dissolved oxygen and field phosphorus were determined onsite using a colorimetric photometer. mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25°C; ---, no analysis]

Line Number	Line Description	Depth Below Pond Bottom (feet)	Distance from Mean Shore (feet)	Date Sampled	Specific Conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH (standard units)	Field phosphorus, dissolved (mg/L as P)
1	South	0.5	-1.1	10/28/04	29.0	10.96	7.60	0.00
1	South	0.5	1.8	10/28/04	69.7	10.19	7.75	0.00
1	South	0.5	4.7	10/28/04	---	---	---	---
1	South	0.5	7.6	10/28/04	142	9.50	7.73	0.00
1	South	0.5	10.5	10/28/04	119	4.58	7.98	0.00
1	South	0.5	13.4	10/28/04	114	2.95	8.39	0.00
1	South	0.5	16.3	10/28/04	110	0.05	8.21	0.00
1	South	0.5	19.2	10/28/04	214	0.04	7.60	0.00
1	South	0.5	22.1	10/28/04	245	0.01	7.39	0.05
1	South	0.5	25.0	10/28/04	238	0.01	7.71	0.02
1	South	0.5	27.9	10/28/04	231	0.01	7.41	0.02
1	South	0.5	30.8	10/28/04	186	0.12	8.21	0.00
1	South	0.5	33.7	10/28/04	176	0.07	7.65	0.00
1	South	0.5	36.6	10/28/04	168	0.04	7.68	0.10
1	South	0.5	39.5	10/28/04	171	2.59	7.23	0.05
1	South	3.0	-1.1	10/28/04	110	0.01	6.19	0.03
1	South	3.0	1.8	10/28/04	98.8	0.00	5.23	0.03
1	South	3.0	4.7	10/28/04	63.1	0.11	5.34	0.03
1	South	3.0	7.6	10/28/04	100	0.12	5.81	0.02
1	South	3.0	10.5	10/28/04	131	0.71	6.91	0.05
1	South	3.0	13.4	10/28/04	104	0.26	6.68	0.05
1	South	3.0	16.3	10/28/04	86.1	0.69	6.91	0.00
1	South	3.0	19.2	10/28/04	165	0.02	6.89	0.03
1	South	3.0	22.1	10/28/04	234	0.02	6.95	0.36
1	South	3.0	25.0	10/28/04	238	0.01	7.12	0.88
1	South	3.0	27.9	10/28/04	230	0.03	7.17	0.36
1	South	3.0	30.8	10/28/04	225	0.01	7.34	0.47
1	South	3.0	33.7	10/28/04	196	0.02	7.31	0.29
1	South	3.0	36.6	10/28/04	171	0.02	6.97	0.96
1	South	3.0	39.5	10/28/04	155	0.07	6.55	1.04
2	North	0.5	-1.1	10/28/04	168	0.01	7.24	0.00
2	North	0.5	1.8	10/28/04	140	0.13	7.17	0.00
2	North	0.5	4.7	10/28/04	191	0.25	7.61	0.00
2	North	0.5	7.6	10/28/04	198	0.02	7.55	0.02
2	North	0.5	10.5	10/28/04	162	0.00	7.71	0.00
2	North	0.5	13.4	10/28/04	170	0.06	7.76	0.00
2	North	0.5	16.3	10/28/04	149	0.01	7.82	0.00
2	North	0.5	19.2	10/28/04	183	0.00	7.87	0.03
2	North	0.5	22.1	10/28/04	212	0.00	8.23	0.00
2	North	0.5	25.0	10/28/04	211	0.02	8.20	0.07
2	North	0.5	27.9	10/28/04	188	0.14	7.86	0.00
2	North	0.5	30.8	10/28/04	113	1.53	7.47	0.00
2	North	0.5	33.7	10/28/04	110	0.72	7.39	0.00
2	North	0.5	36.6	10/28/04	123	0.35	6.97	0.00
2	North	0.5	39.5	10/28/04	113	0.37	6.54	0.00
2	North	3.0	-1.1	10/28/04	108	0.02	6.29	0.00
2	North	3.0	1.8	10/28/04	131	0.00	6.69	0.02
2	North	3.0	4.7	10/28/04	253	0.01	7.10	0.05
2	North	3.0	7.6	10/28/04	226	0.04	7.03	0.10
2	North	3.0	10.5	10/28/04	192	0.00	7.20	0.05
2	North	3.0	13.4	10/28/04	172	0.04	7.38	0.11
2	North	3.0	16.3	10/28/04	166	0.10	7.54	0.29
2	North	3.0	19.2	10/28/04	208	0.02	7.48	0.02
2	North	3.0	22.1	10/28/04	222	0.10	7.23	1.22
2	North	3.0	25.0	10/28/04	206	0.05	7.27	0.21
2	North	3.0	27.9	10/28/04	179	0.05	7.56	0.03
2	North	3.0	30.8	10/28/04	121	0.08	7.19	0.05
2	North	3.0	33.7	10/28/04	114	0.03	7.06	0.02
2	North	3.0	36.6	10/28/04	129	0.03	6.54	0.02
2	North	3.0	39.5	10/28/04	103	2.16	5.91	0.00

APPENDIX F

Lessons Learned

LESSONS LEARNED (DESIGN AND IMPLEMENTATION)

The project was executed smoothly by the AFCEE team from finalization of the design and associated permitting and testing of monitoring technology through construction of the barrier and monitoring network and the post-construction performance monitoring effort. The barrier project has been in the planning/development stages for several years. The geochemical barrier project represents the culmination of extensive study and monitoring efforts associated with the pond and the phosphorus plume nearby, laboratory and field pilot testing of ZVI media, permitting, and field construction. The lessons-learned from the final stages of the geochemical barrier project are summarized as follows:

Design, Workplan and Permitting

- Field scale tests (test plots) and laboratory bench (column) tests, requiring many months to complete, were very important for establishing design parameters with sufficient certainty.

- Final design and permitting of projects of this nature require extensive coordination between stakeholders and cooperation between various regulatory agencies and other parties.

- Design and construction plans need to be flexible enough to be responsive to considerations for protecting natural and historical resources during construction.

Field Construction

- The HDPE grid mat system provided an excellent surface upon which to move equipment and supplies to the work area while spreading loads and protecting the shoreline surface.

- Prior to barrier construction, the gravel/cobble pond bottom surface in the target area was anticipated to be a fairly significant characteristic of the pond bottom subsurface. The gravel/cobble layer proved to be only surficial indicating that it is an armor, or lag, resulting from erosional wave action. It is expected that with time this surface will redevelop.

- Cultural resources were not discovered in any of the excavated sediments in the barrier area.

- The overall "shore-side" approach to the sediment excavation and mixing required temporary dewatering of the area for equipment. This worked well in the shallow setting in terms of construction efficiency and controlling turbidity.

- The amount of water that would infiltrate beneath the bladder cofferdams and potentially between the joints was initially underestimated. The amount of water infiltration was estimated to be around 400 gpm. This number was off by about a factor of ten. The additional water was managed with larger pumps and modified filtration systems while maintaining turbidity and siltation control. Other than driving sheet piles to create a cutoff wall, which would have been expensive and more damaging to the natural resources, the only other alternative may have been a "Port-a-dam" system. This system uses steel frames linked together to form a support structure around the area that needs to be dewatered. A non-permeable liner is then attached to the top of the support structure above the water line. The liner is then rolled down the outside face of the structure extending approximately 40 ft beyond the structure on the waterbody bottom. This liner is then sandbagged and sealed as water is pumped from inside the cofferdam area.

Implementation Costs

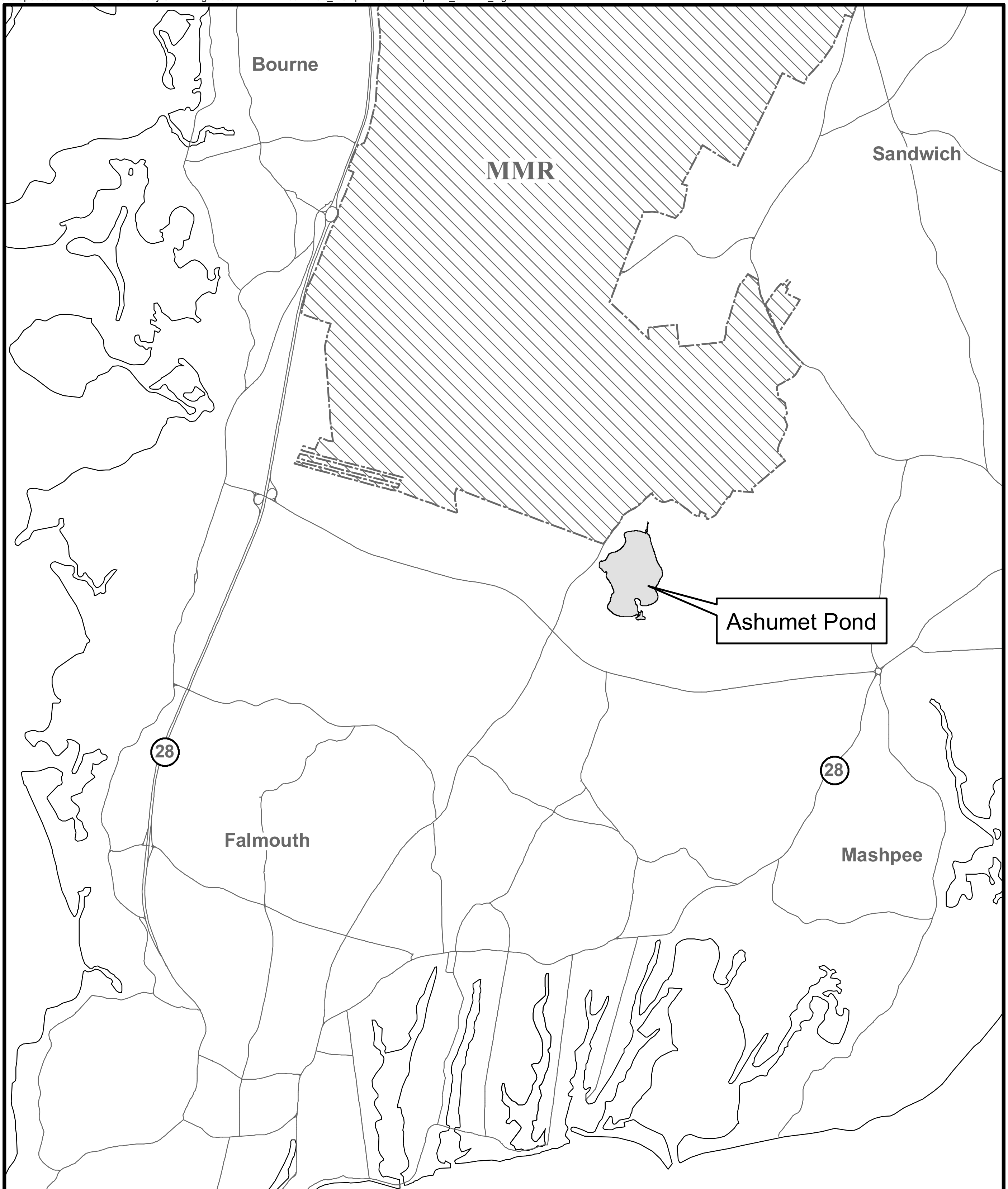
It was originally estimated that this project would involve installation of a barrier using wet/submerged excavation methods and also using a specialized pontoon/floating excavator that would have mobilized from New Orleans, Louisiana. During the permitting and workplan development phase of the project, the team modified the construction approach to utilize the water-bladder cofferdams (Aquabarriers®), dewater the area, and use conventional construction equipment to excavate and mix ZVI with pond bottom sediments. This revised approach resulted in lower mobilization and demobilization costs. These savings, in addition to analytical cost reductions and other savings, resulted in an overall cost savings of $30,663 over the original construction cost estimate for the project. Table 1 provides a summary of costs for the construction of the geochemical barrier.

Table 1

INSTALLATION COSTS

Task Description	Original Budget	Actual Costs
Mobilization	$23,642	$6,650
Submittals/Implementation Plans	$16,313	$3,530
Sampling Soil and Sediment	$32,824	$13,635
Cost Estimate Preparation	$7,179	$5,982
Barrier Construction Activities	$147,703	$192,748
Demobilization	$23,643	$8,789
General Requirements	$84,959	*$74,266
Total	**$336,263**	**$305,600**

*Includes estimated cost for project closeout activities.



Data Source: AFCEE, MMR-AFCEE Data Warehouse

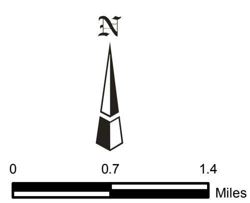


FIGURE 1

LOCATION OF ASHUMET POND

AFCEE - Massachusetts Military Reservation

Ashumet Pond Phosphorous Barrier Project

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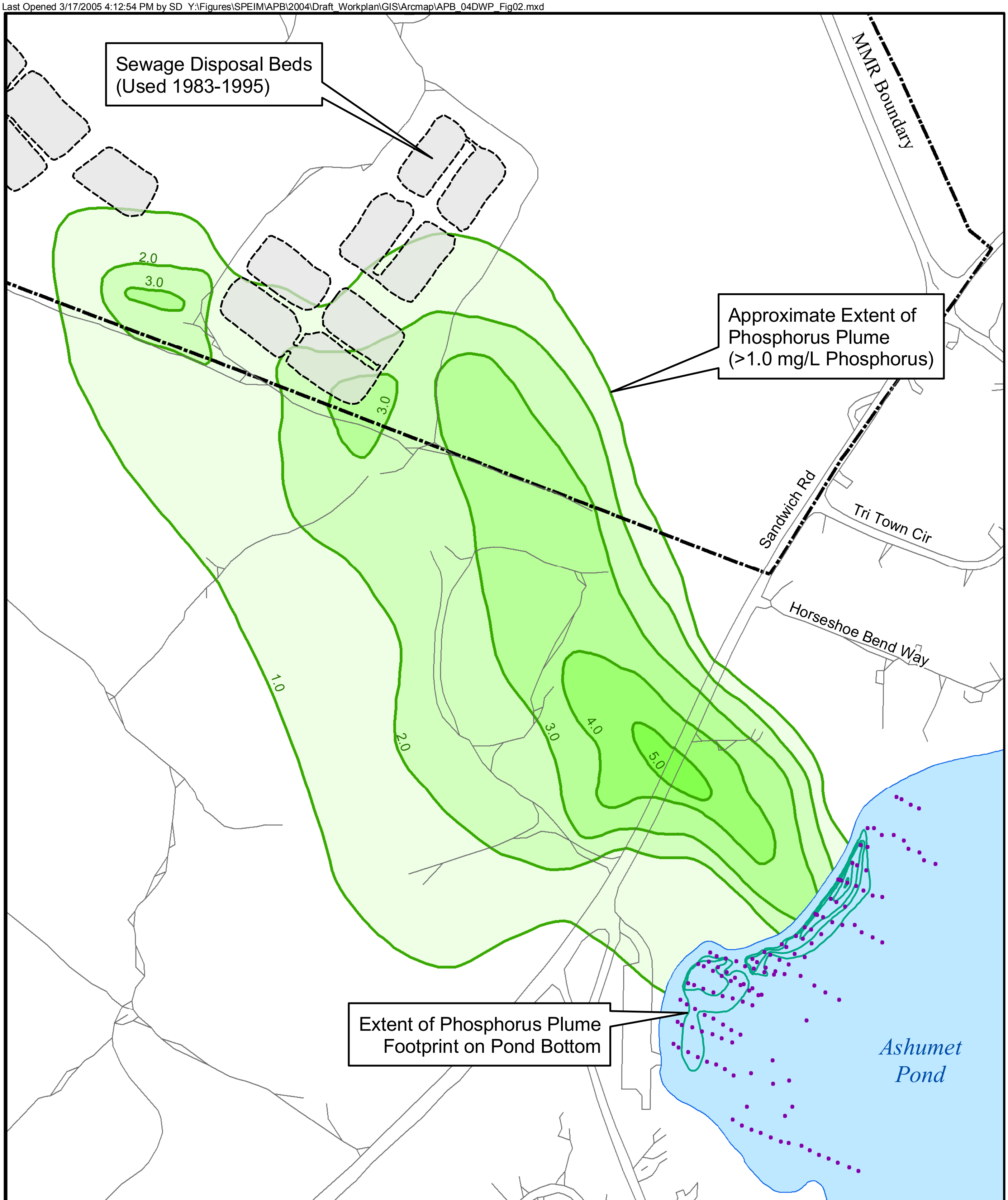

FIGURE 2

PHOSPHORUS PLUME FOOTPRINT IN ASHUMET POND (1999)

AFCEE - Massachusetts Military Reservation

Ashumet Pond Phosphorus Barrier Project

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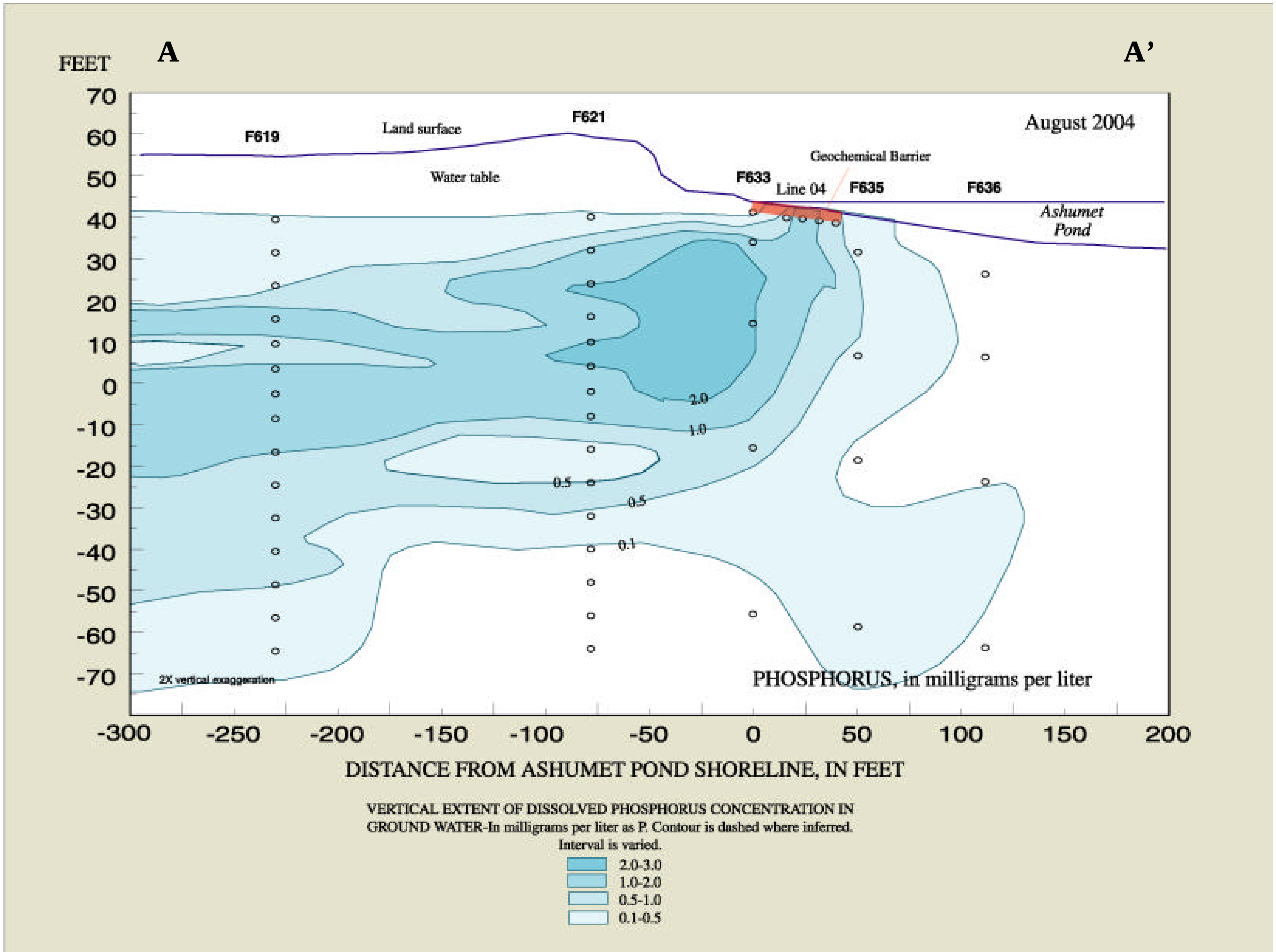

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FIGURE 3
Phosphorus Plume Cross Section and Geochemical Barrier

Courtesy USGS

Legend

Silt Barrier

Ashumet Pond Barrier

N

0 40 80 Feet

Data Source: AFCEE, May 2004, MMR-AFCEE Data Warehouse
1997 Aerial Photography.

FIGURE 4

EXTENT OF OUTER SILT BARRIER

AFCEE - Massachusetts Military Reservation

Ashumet Pond Phosphorous Barrier Project

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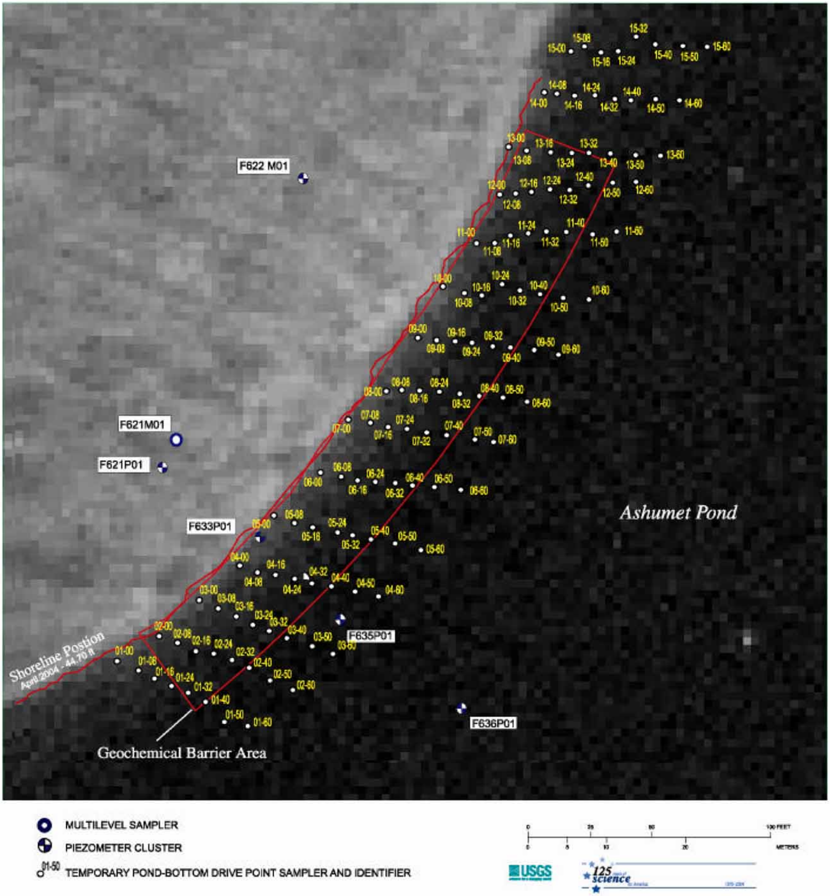

Figure 5. Locations of temporary drive points installed and sampled on June 29 - July 2, 2004, to delineate the phosphorus discharge area.

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FIGURE 5
Preinstallation Baseline Monitoring – Temporary Drivepoint Locations

FIGURE 6
Temporary Drivepoint Sampling

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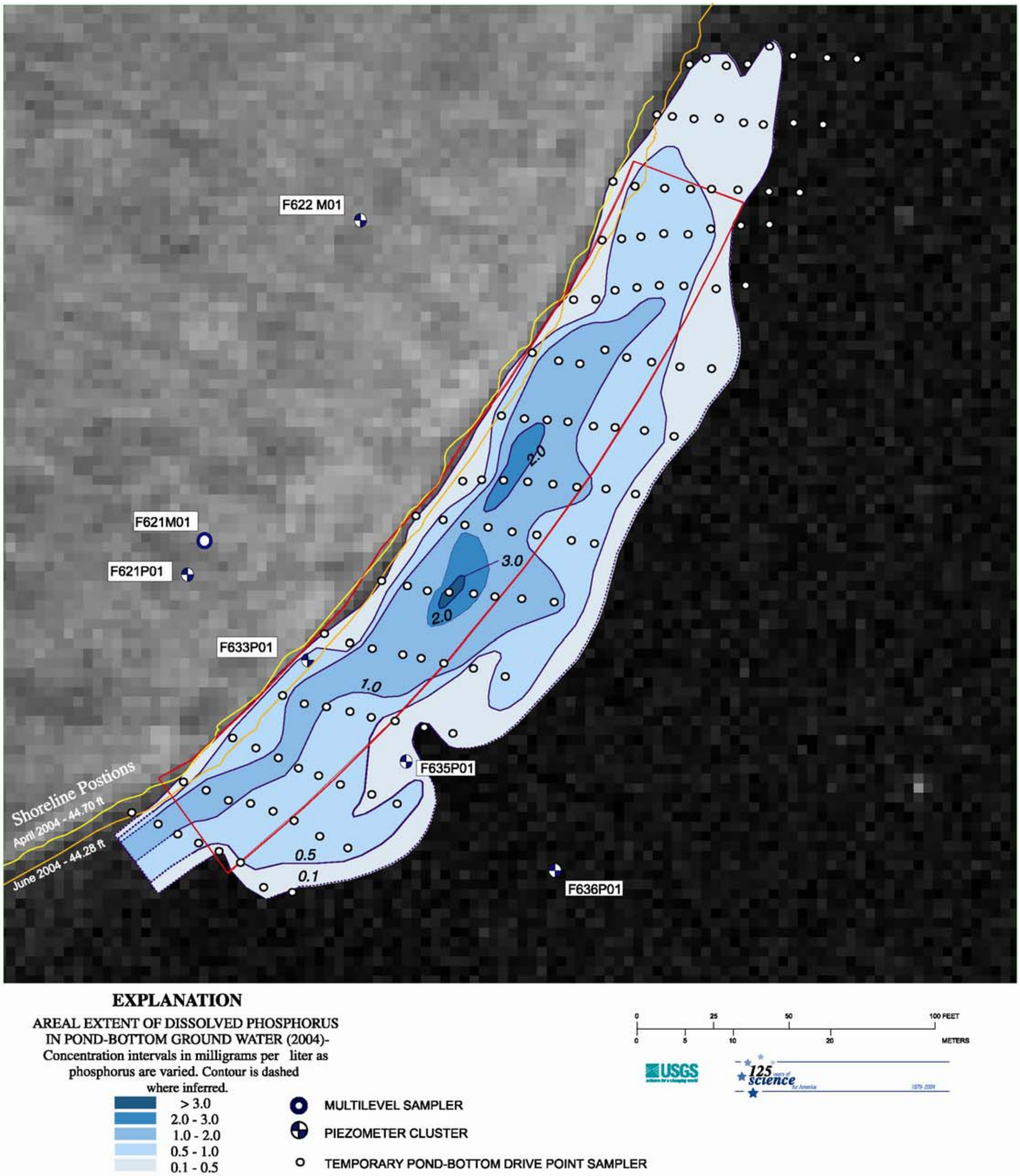

Figure Areal distribution of dissolved phosphorus in pond-bottom ground water in the proposed geochemical barrier area, Ashumet Pond, Massachusetts, June 29 - July 2, 2004.

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FIGURE 7
Preinstallation Baseline Monitoring – Dissolved Phosphorus in Pond-Bottom Groundwater

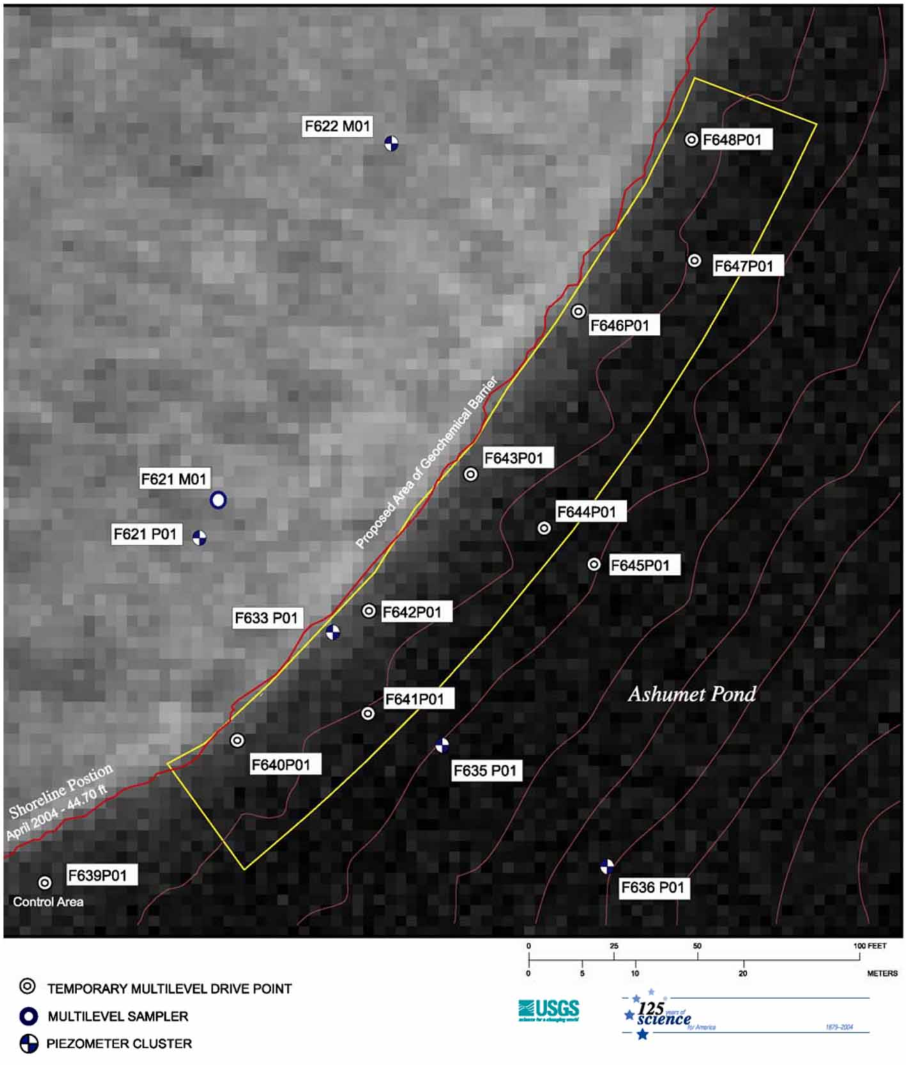

Figure 8. Locations of temporary multilevel drive point locations measured during the week of July 19, 2004, prior to barrier installation. (Total multilevel drive points = 10).

FIGURE 9
HDPE Grid/Mat System Installation

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FIGURE 10
Work Area Dewatering

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FIGURE 11
Excavation and Mixing Activities

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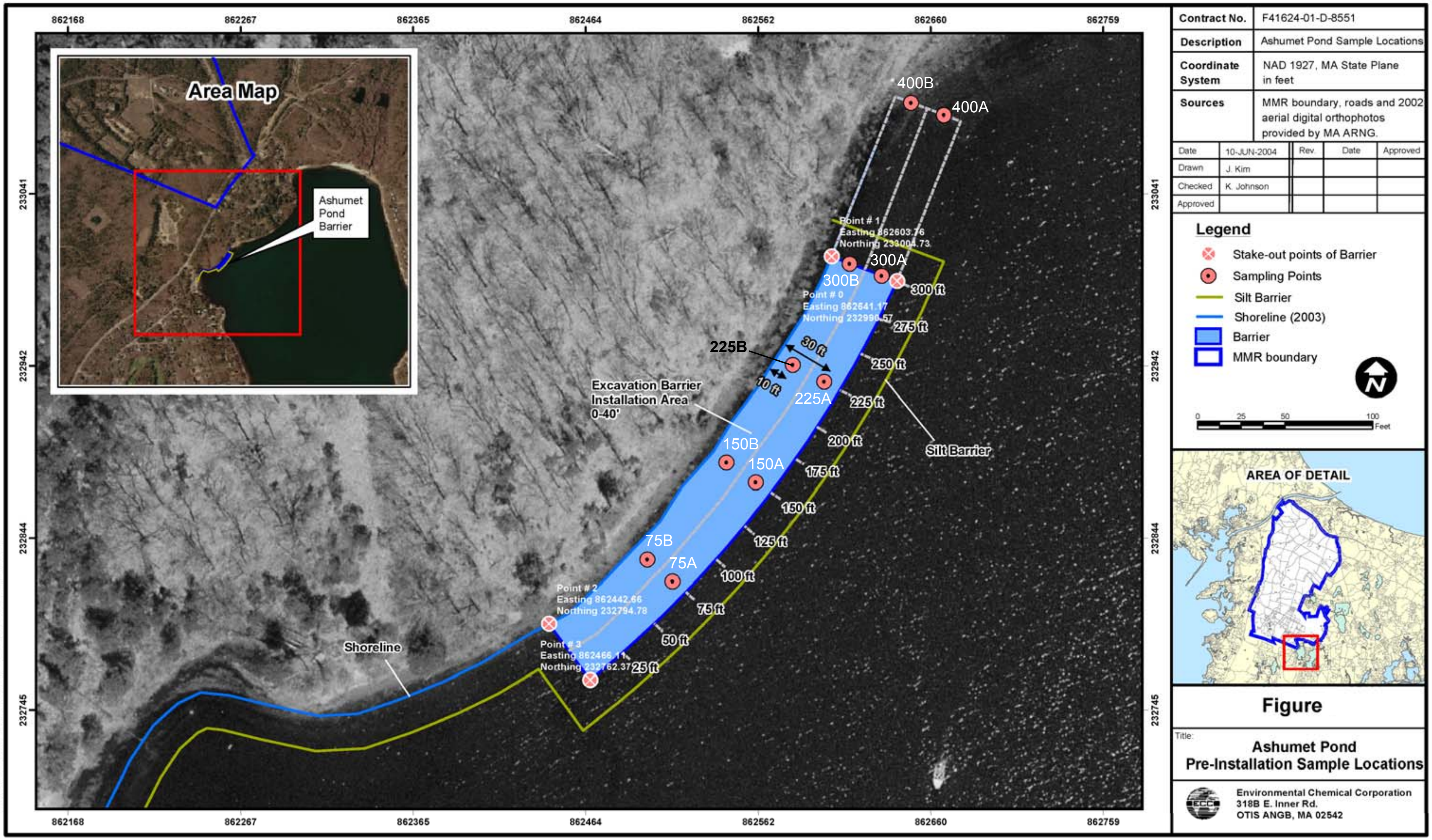

FIGURE 12
Location of Pre-Installation Shoreline Sediment Samples

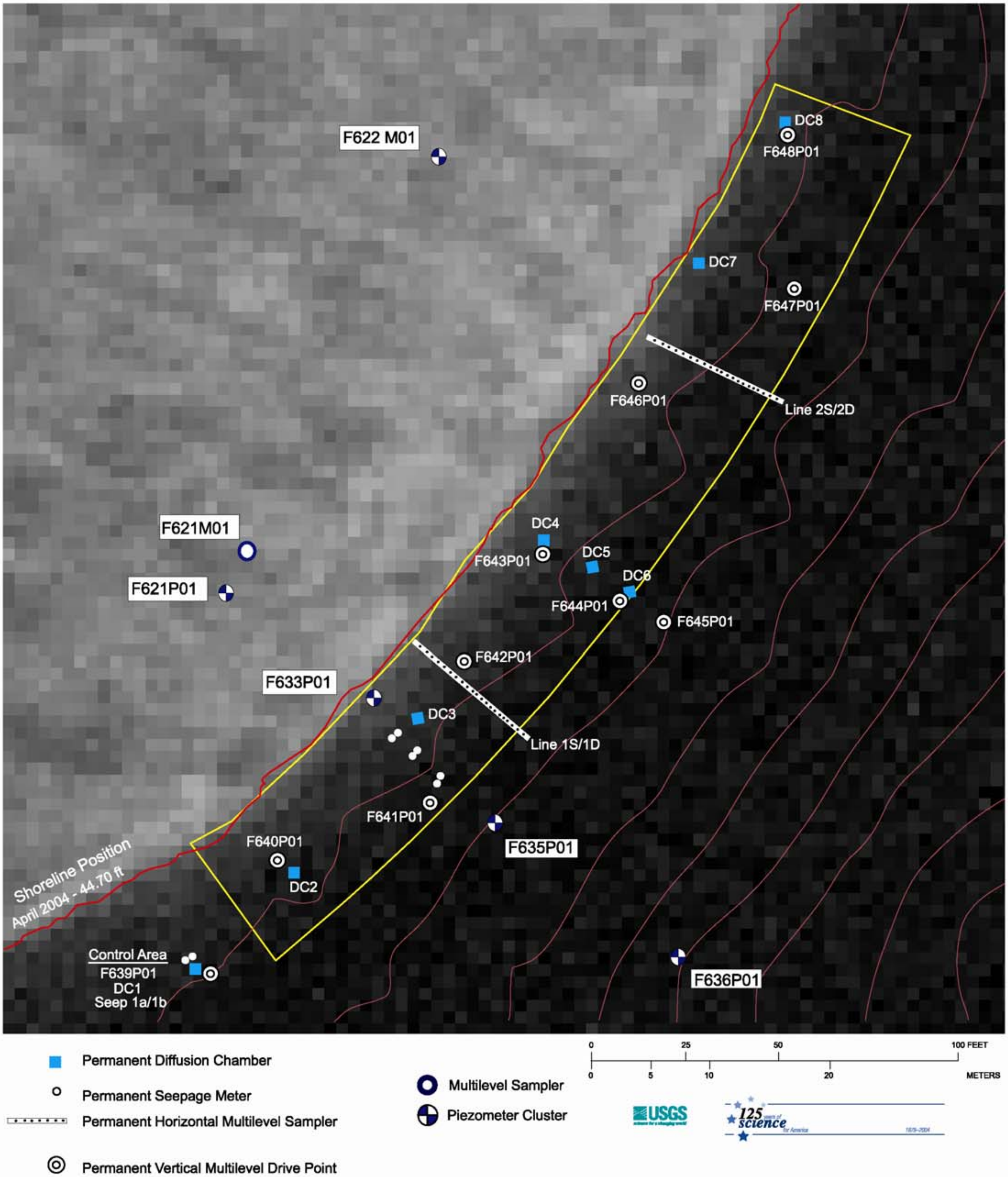

Figure Final locations of permanent seepage meters, multilevel drive points, horizontal multilevel samplers, and diffusion chambers in geochemical barrier area of Ashumet Pond. (Total seepage locations = 4, total multilevel drive points = 8, total MLS lines = 2 (coupled), total diffusion chamber locations = 8).

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FIGURE 13
Barrier Performance Monitoring Network Location Map

FIGURE 14
Multilevel Drivepoint and Diffusion Chamber Samplers

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FIGURE 15
Multilevel Drivepoint and Diffusion Chamber Samplers – Installed

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FIGURE 16
Horizontal Multilevel Sampler Being Installed

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FIGURE 17
Seepage Meters – Installed

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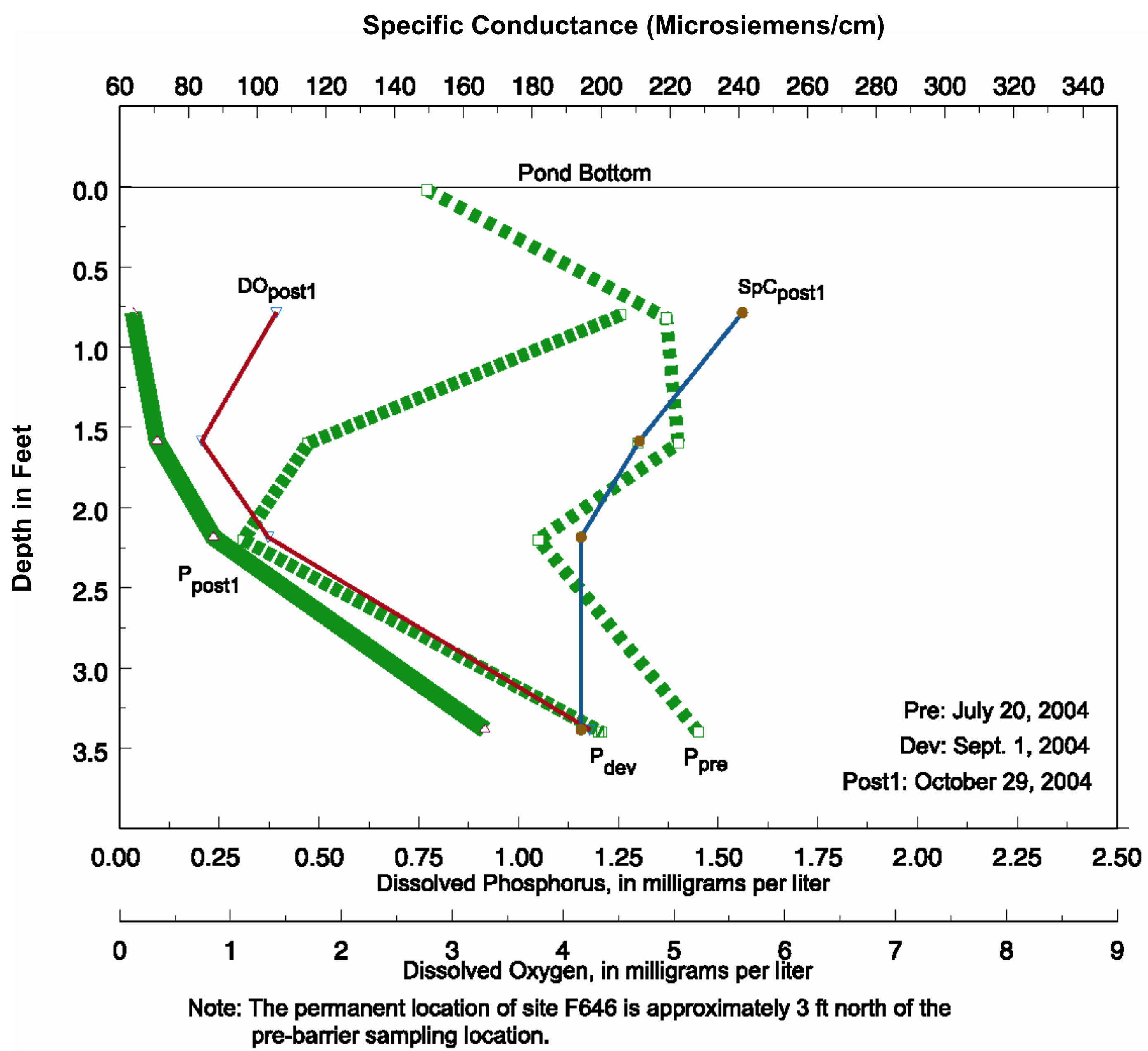

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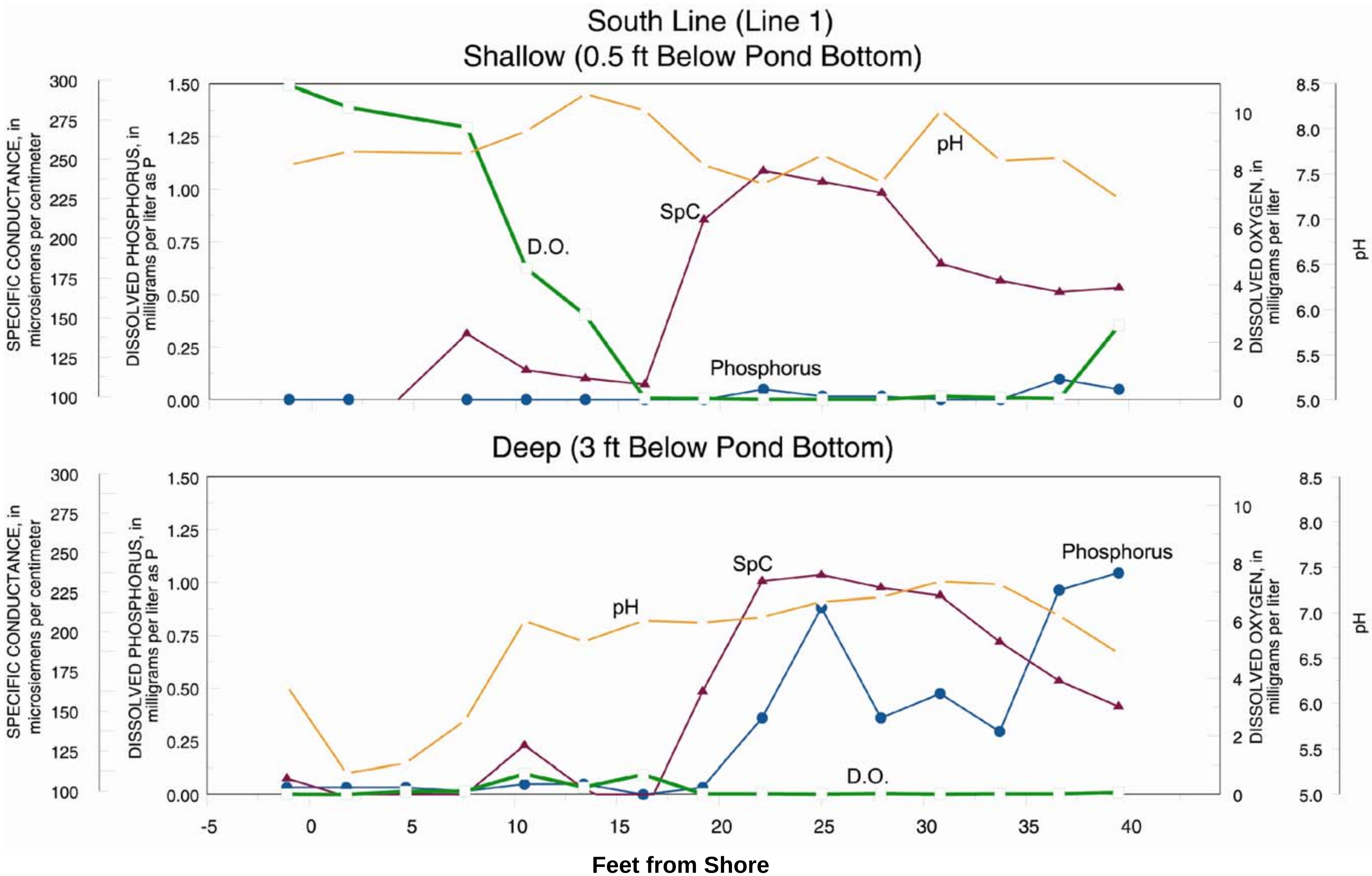
FIGURE 18
Multilevel Sampler F646P01 – Phosphorus Data



Field parameters and dissolved phosphorus concentrations in two horizontal multilevel samplers installed at 0.5 and 3.0 feet below the pond bottom along the southern most of two transects in the geochemical barrier.

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FIGURE 19
Southern Horizontal Multilevel Sampler – Phosphorus Data

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Legend

Ashumet Pond Barrier

Actual Sample Location

N

0 25 50

Feet

Data Source: AFCEE, May 2004, MMR-AFCEE Data Warehouse
1997 Aerial Photography

FIGURE

TEMPORARY DRIVE POINT SAMPLE LOCATIONS - ASHUMET POND BARRIER PERFORMANCE EVALUATION

AFCEE - Massachusetts Military Reservation

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FIGURE 20

Post Installation Temporary Drivepoint Locations (November, 2004)

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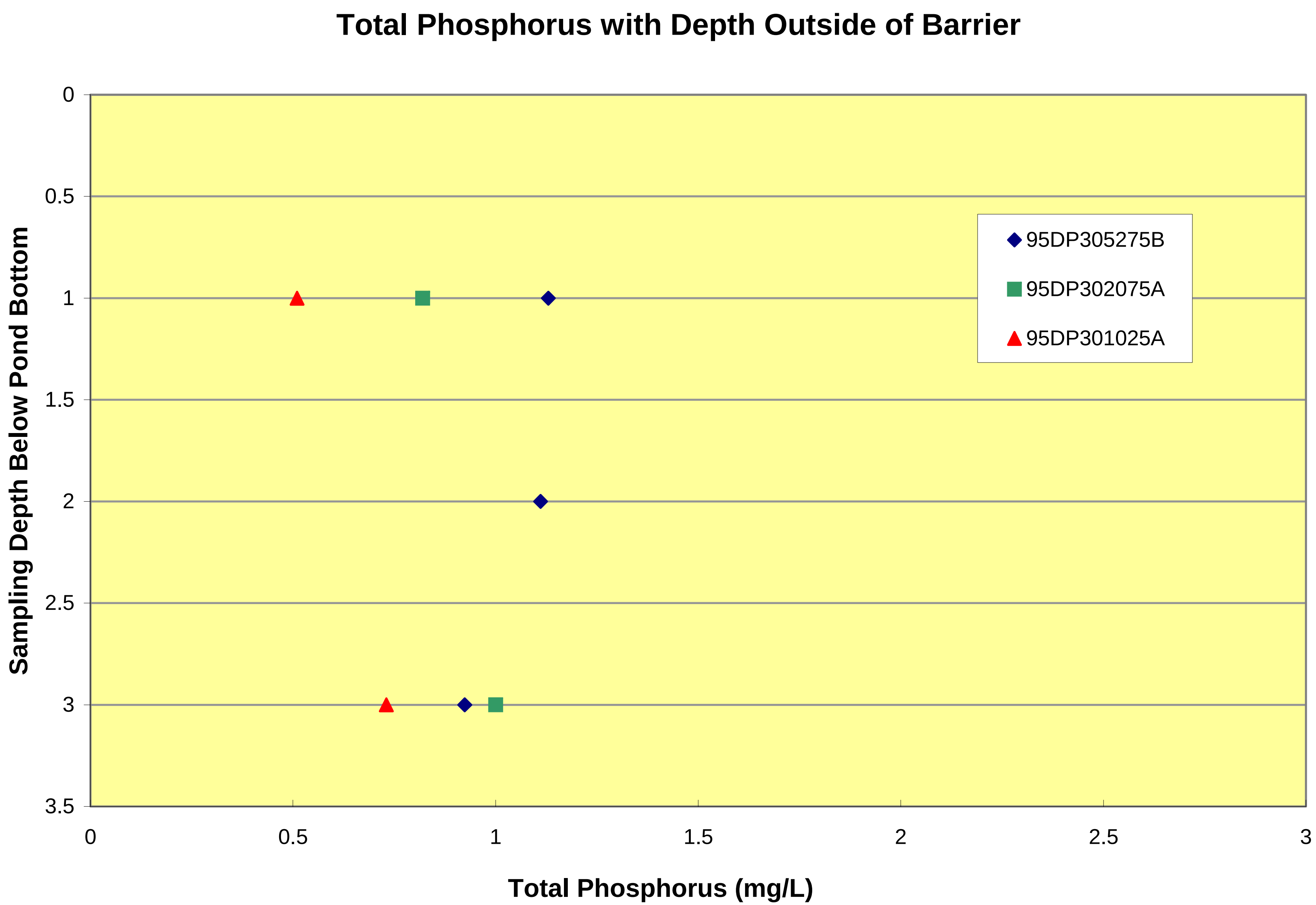

FIGURE 21
Phosphorus with Depth Outside Barrier

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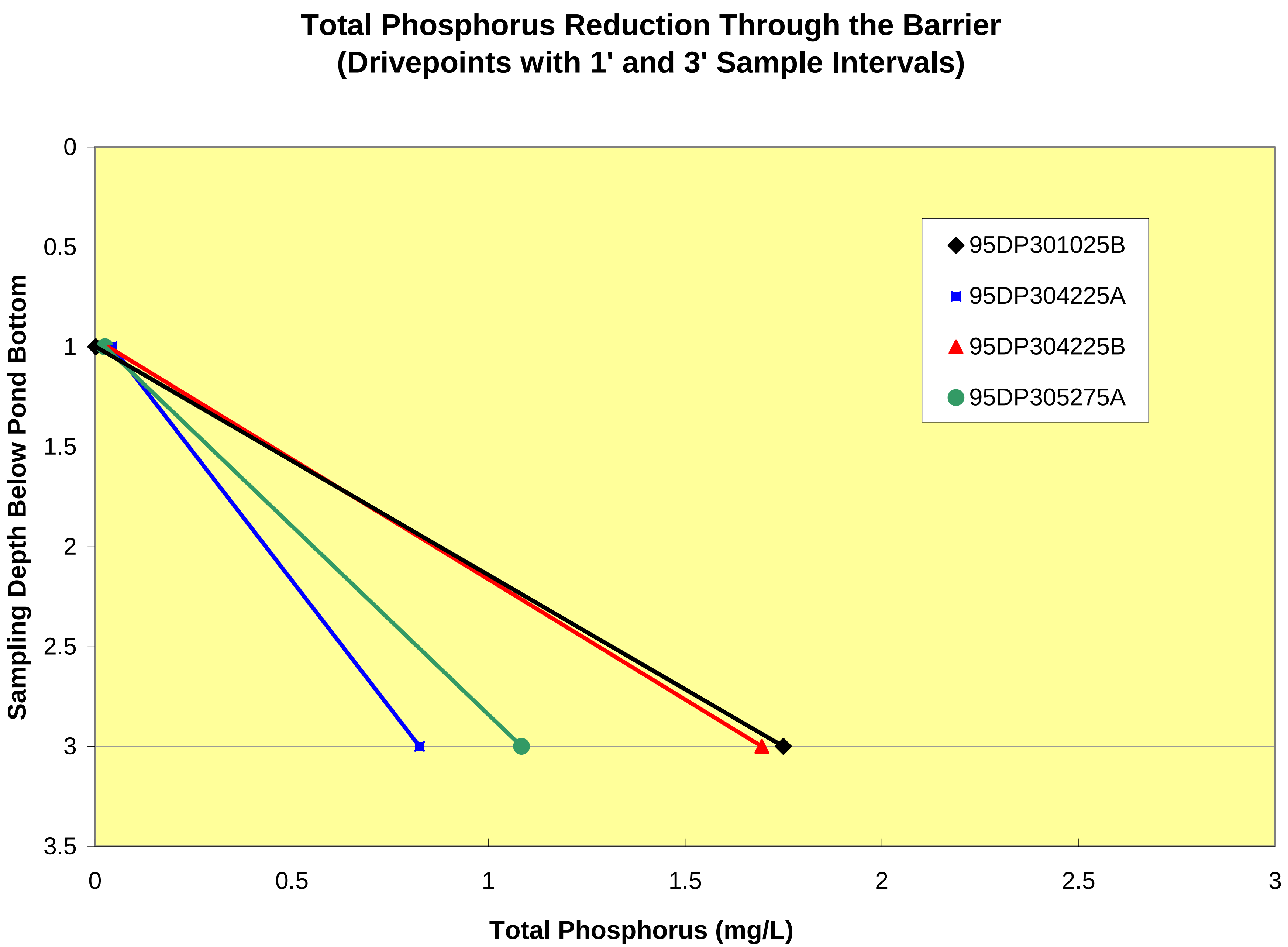

FIGURE 22
Phosphorus Reductions Through the Barrier – Drivepoints with 1' and 3' Sample Intervals

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Total Phosphorus Reduction Through the Barrier
(Drivepoints with 0.5', 1', 2', and 3' Sample Intervals)

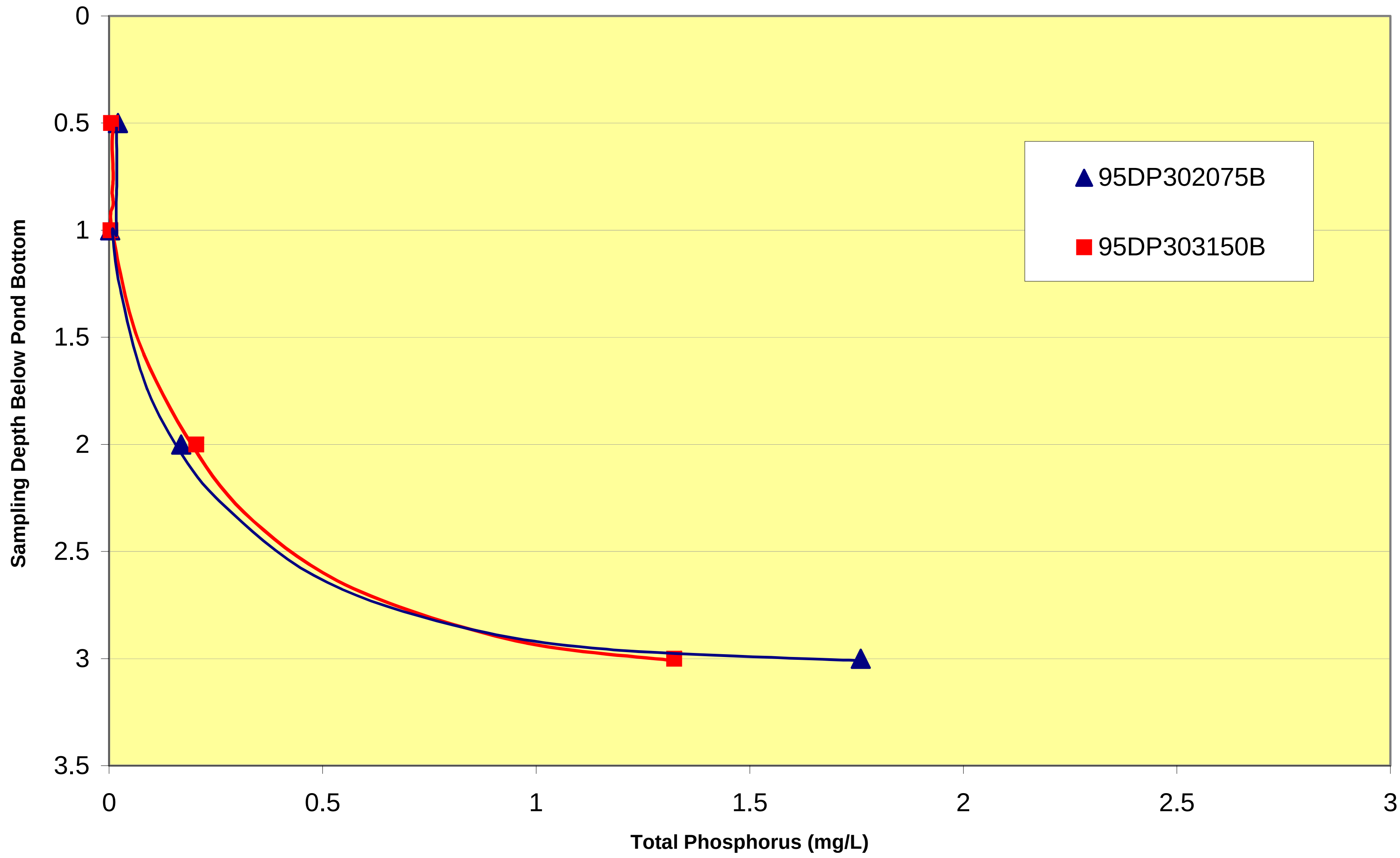

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FIGURE 23
Total Phosphorus Reduction Through the Barrier --
Drivepoints with .5', 1', 2', and 3' Sample Intervals

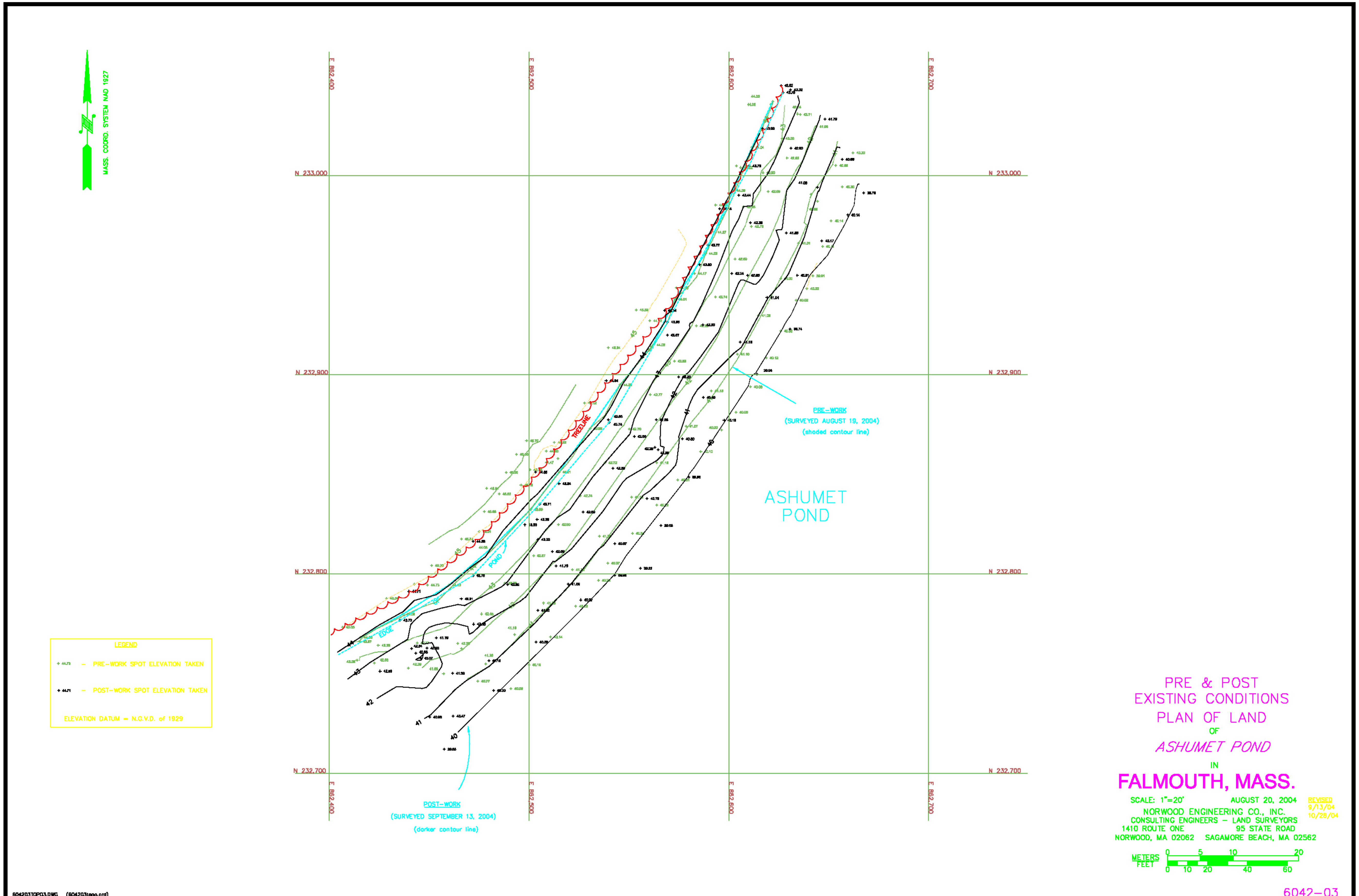

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FIGURE 24
Shoreline Bathymetry – Before and After Barrier Construction

Table 1

Geochemical Barrier Design Summary

*NOTE: Actual application differed from design as described in Section 4.0

Element	Description
Barrier Area	The barrier area shall extend 300 feet along the shoreline and a maximum of 40 feet offshore (from a pond elevation of approximately 44.5 feet above mean sea level, consistent with the September 2003 shoreline) and shall cover a large portion of the phosphorus plume discharge footprint Figure 4 shows the planned barrier footprint.
Barrier Depth	Pond bottom materials shall be excavated to a maximum depth of three feet below the pond bottom surface. ZVI shall be mixed with sandy sediments and placed in a barrier layer approximately two feet in thickness at the bottom of the excavation. Gravel/cobble material greater than two inches in diameter and residual finer material shall be used to provide a protective one foot layer at the surface and a habitat comparable to pre-barrier conditions.
Iron Addition	An estimated 33,750 kilograms (37 tons) of ZVI will be needed over then entire barrier volume. This material will be generally distributed (mixed) with pond bottom materials to a depth of approximately three feet below the pond bottom surface. On a weight basis, the ZVI will represent approximately 3% of the two-foot barrier layer. On a volume basis, this will be approximately 2% of the two-foot barrier layer.
Turbidity Control	Three sequential excavation areas each 100 feet by 50 feet are planned. The primary means of controlling turbidity will be by dewatering the work areas through use of a flexible cofferdam approach. These cofferdams consist of movable bladders (inflated with water) that rest on the pond bottom. Once the bladders are filled and joined, pond water will be pumped from the area. A temporary sump will be established and water will be continuously pumped to maintain dry conditions. This water will be filtered through bag filters prior to discharge. The water will be discharged to a pond area contained by a floating boom/silt-curtain structure. This floating boom/silt-curtain structure will enclose the entire work area from the Ashumet Pond state boat ramp northeast to the barrier construction area. A silt fence will also be used on the landward side of the work area to ensure sediment stays within the work zone.

Element	Description
Resource Protection during Construction	Three excavation sub-areas will be sequentially contained by an Aquabarrier® cofferdam structure during excavation activities. The additional floating boom/silt curtain will be installed for additional turbidity control/spill containment protection. The silt fence will be used on the landward side boundary of the work area. Excavation equipment will be moved from the boat ramp to the work area via the pond shore at the beginning of the project and will be moved back from the work area once the work is completed to minimize traffic across the shoreline. Supplies (primarily ZVI) will be delivered to the excavation/mixing work area over water on a float or barge. During the construction period, the excavation equipment will be stored on the shoreline within the work area. A security guard will be on duty on a 24 hrs a day/7 days per week basis during the construction activities (or as determined to be necessary at the time activities commence). In addition, equipment will be inspected prior to project initiation and throughout the project to ensure that the equipment is in proper and safe working condition.

Table 2

Turbidity Monitoring During Excavation and Dewatering Activities

Turbidity (ntu)	Excavation/Mixing Day			
	08/24/2004	**08/25/2004**	**08/26/2004**	**08/30/2004**
Background Location				
Value	2.6	40.1	23.4	1.1
Discharge Location (within silt curtain)				
Range	2.5-9.8	9.2-98.6	31.7-149.1	8.7-297.1
Average	6.1	42.2	64.6	109.9
Pond near Discharge (outside silt curtain)				
Values	--	--	11.1 and 13.3	4.4 and 5.2
Note: Measurements made every half hour from 0800 through 1630 each day near the outlet of the 12" pump discharge on the south side of the work area.				

Table 3

Iron, Manganese, and Phosphorus in Shoreline Sediments Before, During, and Following Construction

Sample ID	Sample Date	Sample Time	Iron mg/kg	Manganese mg/kg	Total Phosphate as P mg/kg
Pre-Installation Sediment Samples					
03SD01	06/28/2004	11:00	683	321	6
03SD02	06/28/2004	10:30	1890	884	30
03SD03	06/28/2004	14:15	2090	28300	72
03SD04	06/28/2004	12:00	1480	4050	84
03SD05	06/28/2004	15:00	1550	4480	85
03SD06	06/28/2004	14:35	9010	3720	628
03SD07	06/28/2004	15:50	1890	2770	210
03SD08	06/28/2004	15:20	1720	5220	217
03SD09	06/28/2004	16:45	473	948	224
03SD10	06/28/2004	16:15	475	1570	89
30FD08 (DUPLICATE)	06/28/2004	15:20	1500	5200	189
Grid 1 Post-Mixing/Pre-Backfill Samples					
AP-S000101	08/24/2004	15:00	1990	NA	NA
AP-S000102	08/24/2004	16:00	95100	NA	NA
AP-S000103	08/24/2004	16:00	35400	NA	NA
AP-S000104	08/24/2004	16:00	52300	NA	NA
AP-S000105	08/24/2004	16:00	135000	NA	NA
AP-S000106	08/24/2004	16:00	107000	NA	NA
AP-S000107	08/24/2004	16:00	42400	NA	NA
AP-S000108	08/24/2004	16:00	33000	NA	NA
Grid 6 and 7 Post-Mixing/Pre-Backfill Samples					
AP-S0001010 (6 top)	08/26/2004	13:00	50400	NA	NA
AP-S0001011 (6 mid)	08/26/2004	13:00	48700	NA	NA
AP-S0001012 (6 bot)	08/26/2004	13:00	35900	NA	NA
AP-S0001013 (7 top)	08/26/2004	15:00	80400	NA	NA
AP-S0001014 (7 mid)	08/26/2004	15:00	92400	NA	NA
AP-S0001015 (7 bot)	08/26/2004	15:00	49100	NA	NA
Grid 8, 9, and 10 Post-Mixing/Pre-Backfill Samples					
AP-S0001016 (8 top)	08/30/2004	10:00	87700	NA	NA
AP-S0001017 (8 mid)	08/30/2004	10:00	62000	NA	NA
AP-S0001018 (8 bot)	08/30/2004	10:00	88100	NA	NA
AP-S0001019 (9 top)	08/30/2004	13:00	54000	NA	NA
AP-S0001020 (9 mid)	08/30/2004	13:00	24600	NA	NA
AP-S0001021 (9 bot)	08/30/2004	13:00	35200	NA	NA
AP-S0001022 (10 top)	08/30/2004	15:00	66100	NA	NA
AP-S0001023 (10 mid)	08/30/2004	15:00	133000	NA	NA

Sample ID	Sample Date	Sample Time	Iron mg/kg	Manganese mg/kg	Total Phosphate as P mg/kg
AP-S0001024 (10 bot)	08/30/2004	15:00	132000	NA	NA
Post-Installation Confirmation Samples					
AP-S0001025	09/01/2004	09:15	45500	964	10
AP-S0001026	09/01/2004	09:25	46400	922	87
AP-S0001027	09/01/2004	09:35	64600	1430	6
AP-S0001028	09/01/2004	09:45	25300	619	5
AP-S0001029	09/01/2004	09:55	43200	650	5
AP-S0001030	09/01/2004	10:05	51400	599	7
AP-S0001031	09/01/2004	10:15	31900	456	5
AP-S0001032	09/01/2004	10:20	40900	399	7
AP-S0001033	09/01/2004	10:30	27200	366	5
AP-S0001034	09/01/2004	10:40	18000	760	8
AP-S0001035	09/01/2004	10:40	18100	1340	7
AP-S0001036	09/01/2004	10:50	47600	714	6
AP-S0001037	09/01/2004	11:00	25900	688	41
AP-S0001038	09/01/2004	11:10	56000	681	7
AP-S0001039	09/01/2004	11:20	63100	770	5
AP-S0001040	09/01/2004	11:30	30500	1970	6
AP-S0001041	09/01/2004	11:40	67600	897	6
AP-S0001042	09/01/2004	11:50	53800	1040	6
AP-S0001043	09/01/2004	12:00	67500	764	6
AP-S0001044	09/01/2004	12:10	36200	948	5
AP-S0001045	09/01/2004	12:20	13700	734	21

Note:
NA = Not Available (Not analyzed)

Table 4

Average Iron and Manganese in Barrier Sediments Prior to ZVI Addition and Following Barrier Construction

Sampling Date(s)	Total Iron Average (mg/kg)	Total Manganese Average (mg/kg)
6/28/2004 Pre-Installation (10 samples)	2,126	5,224
9/01/2004 Post-Installation (21 samples)	41,638	843